CHAPTER 4
Model Development

SIMULATION OF GROUNDWATER FLOW

The Lower Kissimmee Basin Groundwater Model was developed to simulate 1995 average steady-state conditions. The model will be used to evaluate average steady-state changes to the groundwater levels using projected withdrawals for 2025.

Conceptual Model

In order to simulate the groundwater flow in the model domain, the hydrogeologic framework needed to be simplified for modeling purposes. The conceptual model consists of four aquifers separated by three semi-confining units and underlain by a confining unit. The flow in the aquifers is represented as purely horizontal flow, while the flow through the semi-confining units is only vertical. This gives a quasi-three dimensional model. Vertical flow from Layer 1 to Layer 2 (or Layer 2 to Layer 1), Layer 2 to Layer 3 and Layer 3 to Layer 4 occurs via the semi-confining units (See Vertical Discretization of Model Layers in **Figure 46**). The calibration run of this model simulates average 1995 steady-state conditions. The base run simulates 2000 1-in-10 rainfall conditions. A 1-in-10 rainfall condition or a 1-in-10 year drought event is defined as an event with a return frequency of once in ten years. The model is used to evaluate projected 1-in-10 rainfall conditions for 2025.

Computer Code Selection

Once modeling objectives have been established, and a preliminary understanding of the predominant hydrologic processes within the area of interest has been attained, a model code is selected, which can meet the model development and application objectives. MODFLOW, a code created by the U.S. Geological Survey (USGS), was selected for this purpose for the following primary reasons:

- It has been widely accepted in the groundwater modeling profession for over 15 years.
- The code is well documented and within the public domain.
- The code is readily adaptable to a variety of groundwater flow systems.
- The code is modular and easily facilitates any modifications required to enable its application to the types of unique groundwater flow problems encountered in south Florida

MODFLOW is a three-dimensional, finite difference groundwater flow program developed by McDonald and Harbaugh of the USGS in 1984. A revised version was published in 1988 and additional features were added in the 1996 version, called MODFLOW96.

The SFWMD has modified some of USGS modules to allow for additional functionality. MODFLOW96 simulates groundwater flow in both the anisotropic and heterogeneous layered aquifer systems using a finite-difference "block centered" approach. The SFWMD version of MODFLOW96 enhanced the well package to allow for multiple well files.

MODFLOW with SFWMD Source Code

MODFLOW simulates groundwater flow in aquifer systems using the finite-difference method. The aquifer system is divided into rectangular or quasi-rectangular blocks by a grid (**Figure 44**). The grid of blocks is organized by rows, columns and layers, and each block is commonly called a cell.

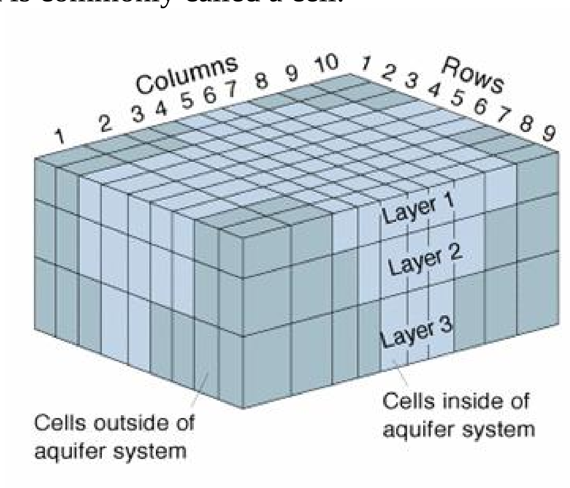

Figure 44. Example of Model Grid for Simulating 3-Dimensional Groundwater Flow.

For each cell within the aquifer system, the user must specify aquifer properties. Also, the user specifies information relating to wells, canals and other hydrologic features for the cells corresponding to the locations of the features. For example, if the interaction between a canal and an aquifer system is simulated, then for each cell traversed by the canal, the required input information includes layer, row and column indices; canal stage; and hydraulic properties of the channel bed. Also, MODFLOW allows the user to specify which cells within the grid are part of the groundwater flow system and which cells are inactive (i.e., outside of the groundwater flow system).

The MODFLOW model code consists of a main program and a series of independent subroutines called modules. The modules, in turn, have been grouped into packages, each dealing with a particular hydrologic process or solution algorithm. The packages used for Lower Kissimmee Basin Groundwater Model simulations, including those developed or enhanced by SFWMD staff and contractors, are shown in **Table 11**.

Table 11. MODFLOW96 Packages Used in the Model.

Package	Description	Notes
Core		
Basic and Output Control	Defines stress periods, time steps, starting heads, grid specifications, units and output specifications	Handles the primary administrative tasks associated with a simulation
Block-Centered Flow (BCF)	Specifies steady-state vs. transient flag, cell sizes, anisotropy, layer types and hydrogeologic data for each layer	Derived primarily from geologic data used to construct the model
Surface Water Stresses and Processes		
Recharge	Simulates areally distributed recharge to a water table during each stress period	Preprocessed using an Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) based ET- Recharge Model
Evapotranspiration (ET)	Simulates removal of water from the water table via transpiration and direct evaporation	Preprocessed using an AFSIRS based ET-Recharge Model; ET rate diminishes with increasing water table depth
River (RIV)	Simulates groundwater interchanges with canals that can either recharge or drain the aquifer	Canal stages are usually based on measured stages or control elevations
Drain (DRN)	Essentially the same as the River package except canals can only drain the aquifer and water removed by the drains is removed permanently from the model	Canal stages are usually based on weir elevations
Water Supply and Management		
Well	Simulates withdrawals from wells	Includes Public Water Supply (PWS) and irrigation wells (Ag); enhanced by the SFWMD to read multiple input files
Solution Algorithms		
Strongly Implicit Procedure (SIP)	A mathematical solution algorithm internal to the model	Enhanced by District to improve model stability

Well Package Modifications and Additions

The well package was modified by the SFWMD staff in 1999 to allow wells to be read from multiple files. This is useful when changes are made frequently to certain types of wells (i.e., public supply wells), while other well data remain fairly static. The primary well file will allow up to two additional unit numbers to be included. The maximum wells identifier in the first file should be sized to accommodate the maximum number of wells in all well files. Additional well files are formatted exactly like the primary well file, except the first line is omitted. These changes allow the reuse flag (-1) to be invoked separately for each file (for transient models). For example, the first file may have 500 wells, the second 20 and the third 10 for the first stress period. In the second stress period, one might decide to reuse all the wells in the first two files, but specify 40 new wells in the third file. For the steady-state model, the multiple well package allowed the separation of the stress by type – Public Water Supply and Irrigation Wells – to ease modifying the files when the model is applied to future conditions.

Strongly Implicit Procedure Package Enhancements

Two alternative enhancements were developed by the SFWMD in 1998 for the Strongly Implicit Procedure (SIP) Package in order to improve or maintain model stability. Both alternatives have added optional variables. If the variables are not used, the Strongly Implicit Procedure package will function normally.

In Alternative 1, two optional variables are added to the second line of the Strongly Implicit Procedure input file. These are HCLOSEMAX and NOSTOP. When the maximum number of iterations is reached, and the maximum head change in a cell is less than HCLOSEMAX, Strongly Implicit Procedure continues to the next time step rather than aborting the simulation. This allows a tight closure criterion (via the original HCLOSE term) for most of the simulation, while tolerating a few problem stress periods. When NOSTOP is included and set equal to 1, the program will not terminate if HCLOSEMAX is violated. Instead, the problem cells are reset to their values at the end of the last time step and a warning message is written to the output file. This is helpful in trying to improve a model with stability problems.

In Alternative 2, four optional variables were added to the Strongly Implicit Procedure input file. These are MNITER and NITERSL on the first input line, and HCLOSEMAX and DACCL on the second input line. MNITER is the minimum number of iterations. NITERSL is the minimum number of iterations before deceleration is allowed. DACCL specifies the fraction by which the simulation will decelerate. HCLOSEMAX is the same as described in Alternative 1. HCLOSEMAX and HCLOSE together serve as an upper and lower bound. Deceleration allows the model to iterate slower, thereby helping maintain stability. The simulation will terminate if the closure criterion exceeds HCLOSEMAX.

Model Design

The model domain for the Lower Kissimmee Basin Groundwater Model is described as follows:

Table 12. Model Domain for the Lower Kissimmee Basin Groundwater Model.

In Decimal Degrees	In Projected Florida East NAD83 HARN Feet
West Corner: -81.654709	Left Corner: 444435.531250
East Corner: -80.593469	Right Corner: 787635.531250
North Corner: 27.764485	Top Corner: 1247082.062500
South Corner: 26.818899	Bottom Corner: 903882.062500

The Lower Kissimmee Basin Groundwater Model projects are in the following coordinate system: NAD 1983 State Plane Florida East FIPS 0901 Feet. The geographic coordinate system name is GCS North American 1983.

The Lower Kissimmee Basin Groundwater Model is composed of a grid containing 130 rows and 130 columns. Each cell is 2,640 feet x 2,640 feet (see **Figure 45**). Lake Okeechobee, Lake Istokpoga and the model cells southeast of the lake are inactive.

The Lower Kissimmee Basin Groundwater Model consists of four layers. The top layer represents the unconfined Surficial Aquifer System, the next layer represents the Upper Floridan Aquifer, the third layer is the Middle Floridan Aquifer and the bottom layer is the Lower Floridan Aquifer. The Intermediate Confining Unit/Aquifer and the Middle Confining Unit 1 and 2 are represented as vertical conductance values between the aquifer layers. (See Vertical Discretization of Model Layers in **Figure 46**.)

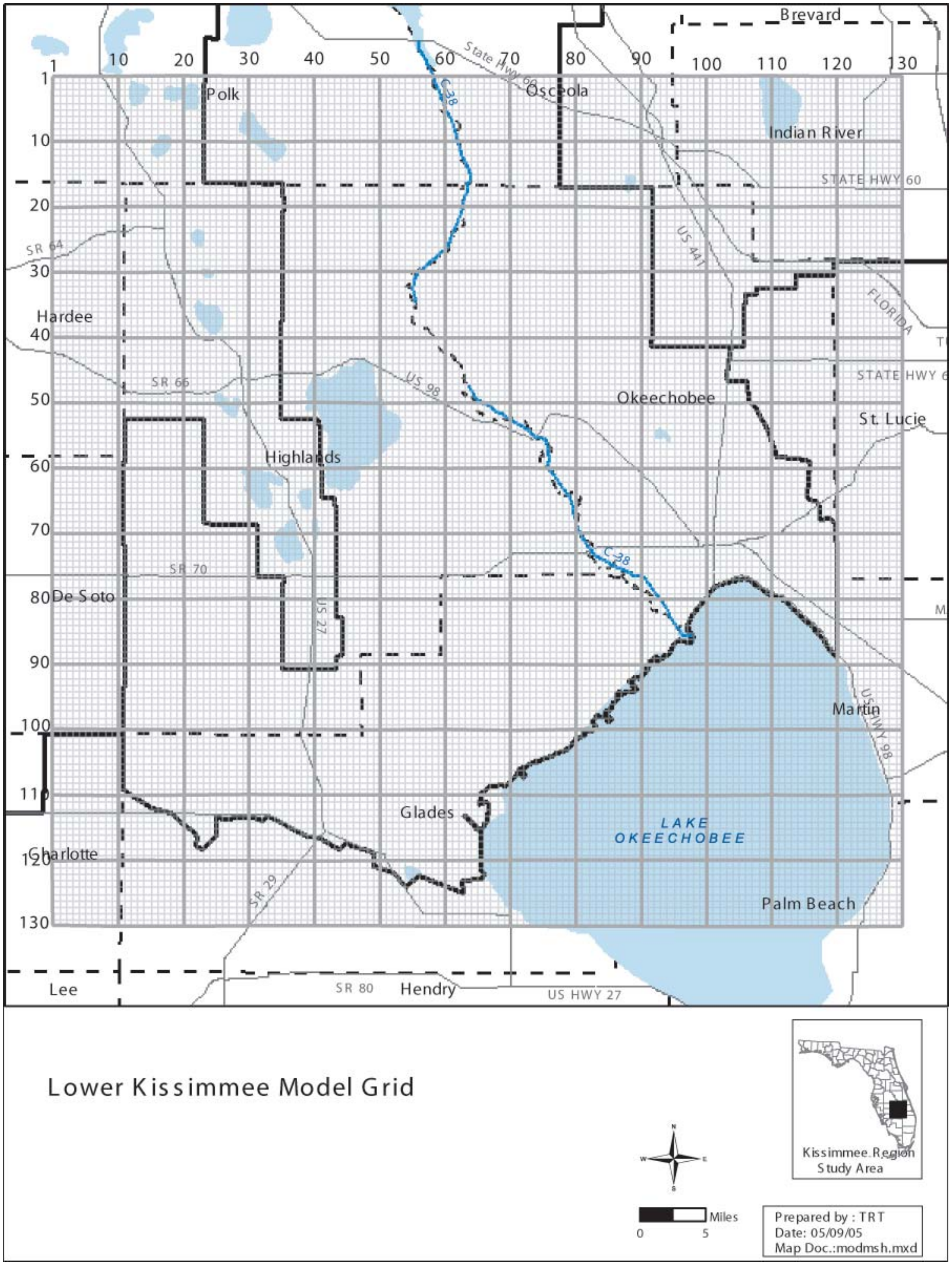

Figure 45. Model Mesh.

Hydrologic Data Input

Table 13 describes the data types needed to create the input files for model.

Table 13. Model Input.

Model Package	Type of Data Required for Active Model Cells	Comments	Figure #
BAS			
	IBOUND Layer 1	Constant along model boundaries; Lake Okeechobee and Lake Istokpoga inactive	47
	IBOUND Layer 2	Constant Heads on along all model boundaries	48
	IBOUND Layer 3	The same as Layer 2	48
	IBOUND Layer 4	Constant Head	N/A
	Starting Heads Layer 1	Used observed values (from Layer 1) where available. Elsewhere 1 foot below topography	50
	Starting Heads Layer 2	Created surface using inverse distance weighting on the average 1995 water levels	51
	Starting Heads Layer 3	Same Starting heads as Layer 2	51
	Starting Heads Layer 4	Same Starting heads as Layer 2	51
BCF			
	Horizontal Hydraulic Conductivity	Assumed 14 ft/day background, 50 ft/day in lakes and rivers; varied for Avon Park Ridge based on calibration	49
	Elevation of Aquifer Bottom	Hydrostratigraphy from kriged surfaces	15
	Vertical Hydraulic Conductivity – VCONT Intermediate Confining Unit	Estimated – Calibration	52
	Transmissivity Upper Floridan Aquifer	Kriged from logs	21
	VCONT Middle Confining 1	Assumed K=1 ft/day, thickness of layer from kriged hydrostratigraphy	92
	Transmissivity Middle Floridan Aquifer	Kriged from logs	26
	VCONT Middle Confining 2	Assumed K=0.5 ft/day, thickness of layer from kriged hydrostratigraphy	55
	Transmissivity Lower Floridan Aquifer	300,000 ft^2 /day	29
Well			
	Public Water Supply (Location, Depth, source, capacity)	Permit database	68
	Irrigation (Ag and Recreation)	Based on land use and permits	69

Table 13. Model Input (Continued).

Model Package	Type of Data Required for Active Model Cells	Comments	Figure #
River and Drains			
	Lake Stages	Web sources: LAKEWATCH, SFWMD DBHYDRO, SWFWMD	56
	River/Stream Stages	DBHYDRO or estimates from topography	56
	Canal Stages	DBHYDRO	56
	Streambed Conductance	Estimated K=1.72 ft/day	56
	Streambed Thickness	1 ft	56
	Canal Profiles	Used as designed books for canals	56
	River/ Stream Profiles	Rivers Estimated ½ slope and river depths. Small streams – estimated 2 ft depth, 20 ft wide	56
	Drain Profile	Estimated Slope 1/4, width estimated from aerial photos. Depth=Width/4	57
	Drain Elevation	Set to depth below land surface	57
	Drain Conductance	K 0.25–0.5 ft/day	57
Recharge			
	Rainfall Data from Gauges	Using NOAA and SFWMD DATA	64
	Rainfall Data applied to Thiessen Polygons		64
	Land Use - 1995 Land Use for Calibration. 2000 Land Use for Verification Run		67
	Soils Series Properties from County Soil Surveys (e.g., water content at specific retention, porosity)		66
ET			
	Land Use - 1995 Land Use for Calibration. 2000 Land Use for Verification Run		67
	ET Extinction Depth	The extinction depth was multiplied x 5 in the calibration process	59
	Topography		5
	Maximum ET Rate	The maximum et rate was multiplied X 1.2 in the calibration process	62
	ET Stations and Thiessen Polygons		61

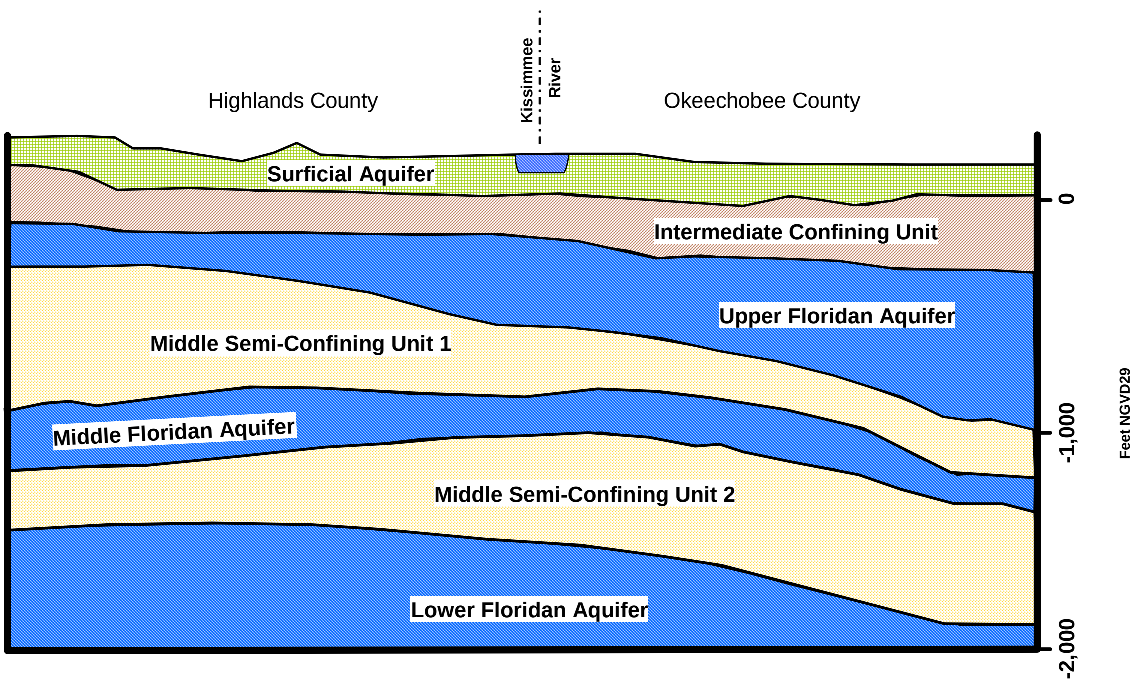

Figure 46. Vertical Discretization of Model Layers.

Boundary Conditions

In Layer1, the Surficial Aquifer System, all model boundaries were set to constant heads. Lake Okeechobee and Lake Istokpoga were inactivated in Layer 1 of the model and their shorelines were set as constant head (**Figure 47**).

In both Layer 2 and 3 (the Upper and Middle Floridan Aquifer layers), the model boundaries were set as constant head (**Figure 48**). The base of the model, the Lower Floridan Aquifer, was set as a constant head.

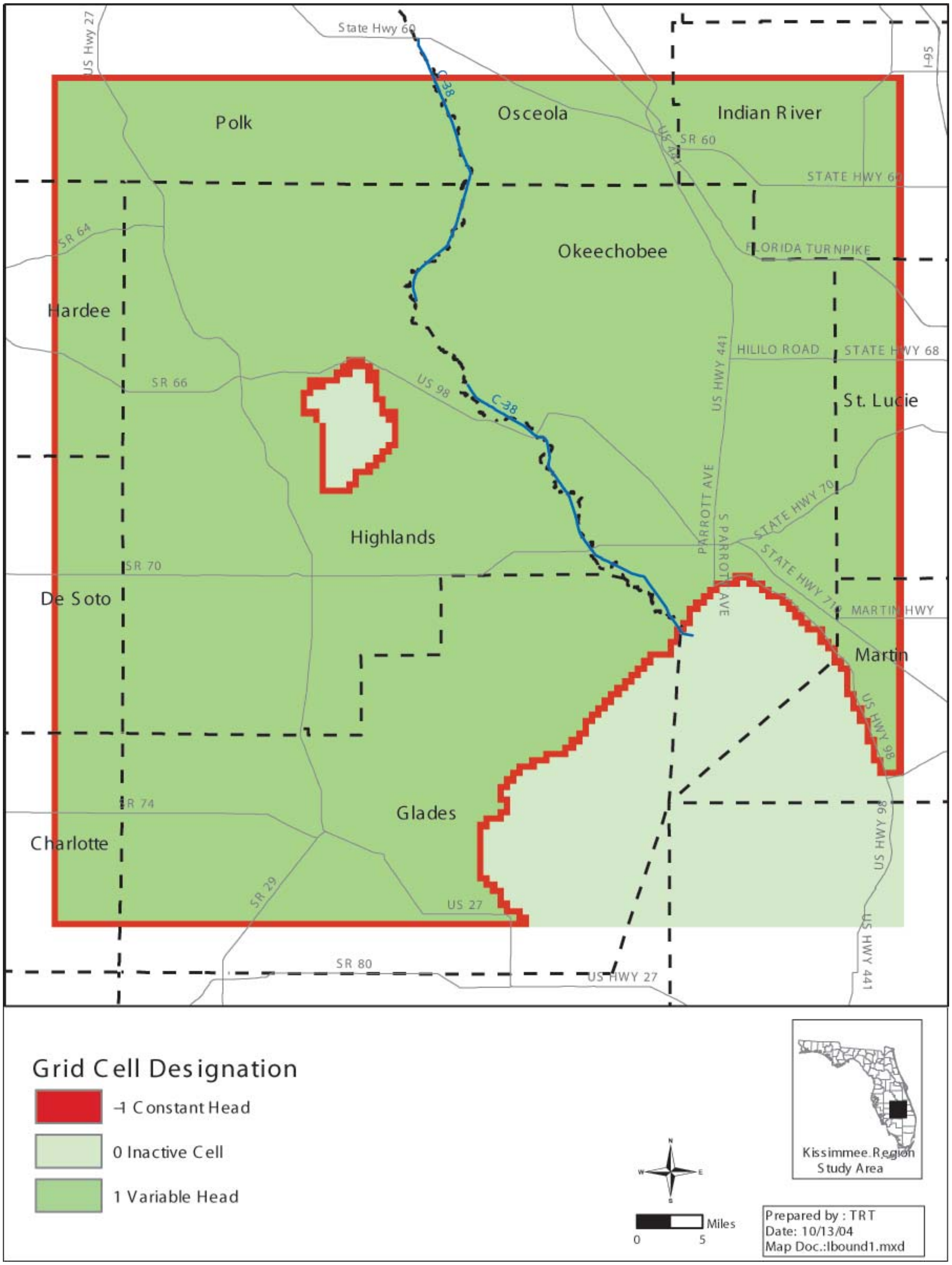

Figure 47. IBOUND Layer 1.

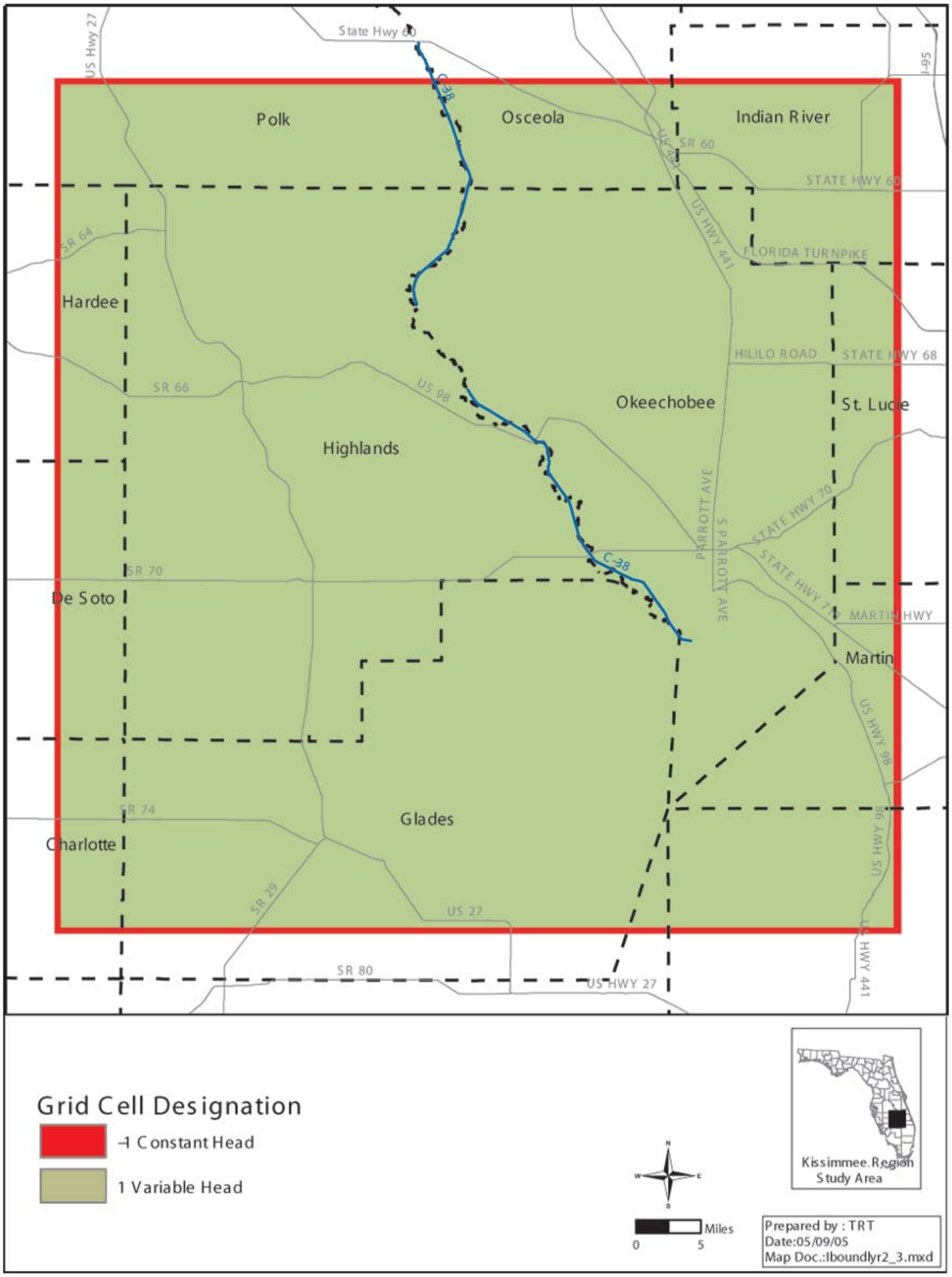

Figure 48. IBOUND Layer 2 and 3.

Hydraulic Conductivities

During the Lower Kissimmee Basin Groundwater Model calibration, various hydraulic conductivity values were tested. When the values were too high (30 ft/day in land areas, 100 ft/day on water), the water levels in the Surficial Aquifer System dropped too low, when the values were too high areas “flooded”. Therefore hydraulic conductivity values were estimated at 14 ft/day for most of the model area. The river and lake area hydraulic conductivity values were set at 50 ft/day and were modified in the Avon Park Ridge for calibration purposes. See **Figure 49** for the distribution of the hydraulic conductivities in the area.

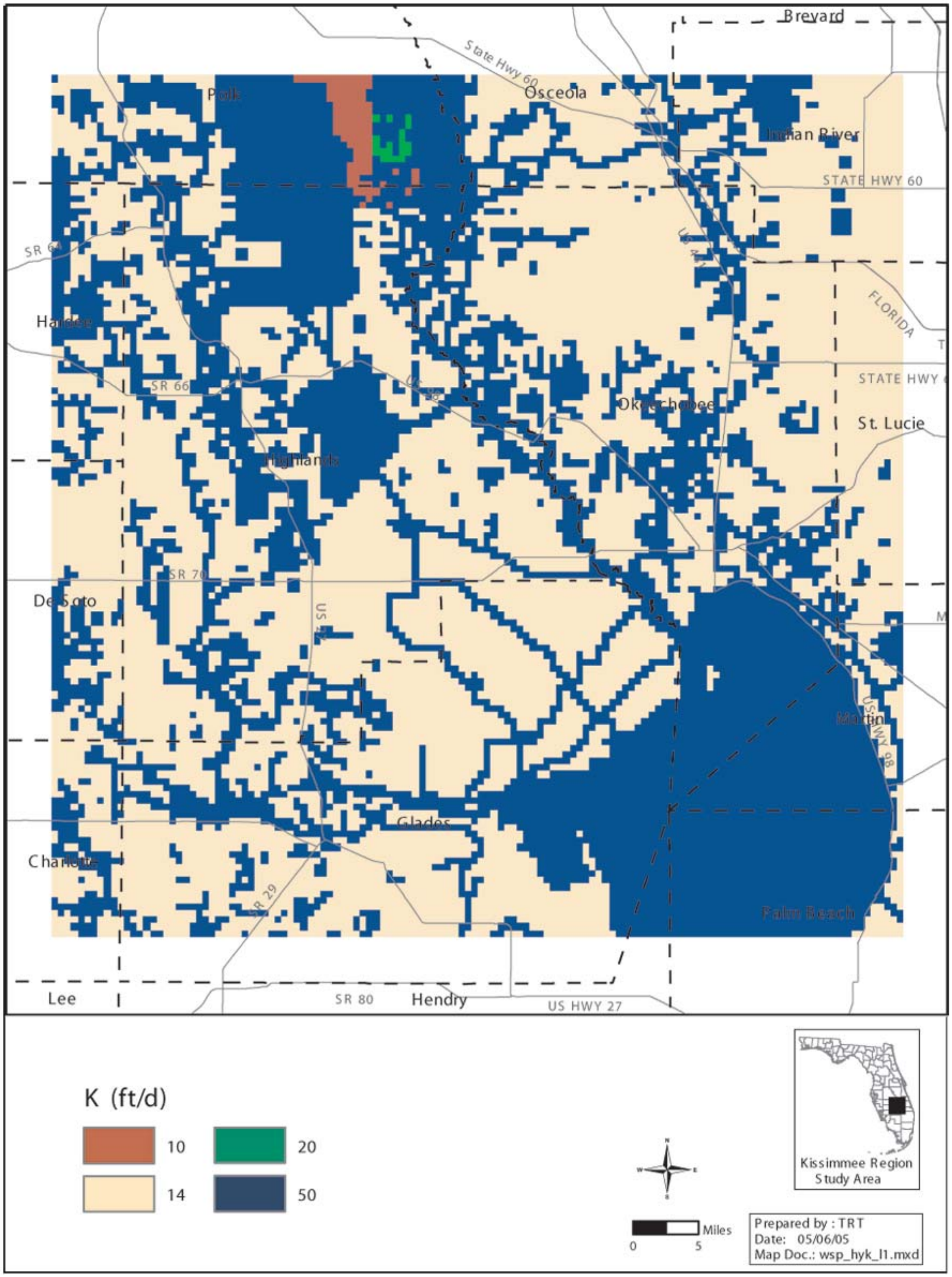

Figure 49. Hydraulic Conductivity K (ft/day) Values Used for Layer 1 (Surficial Aquifer System).

Starting Heads

Layer 1

Starting heads were set for 1 foot below land surface (bls) with the exception of surface water features and observation point sites, which were set to the average 1995 observed value (for locations of observation sites refer to **Figure 50**).

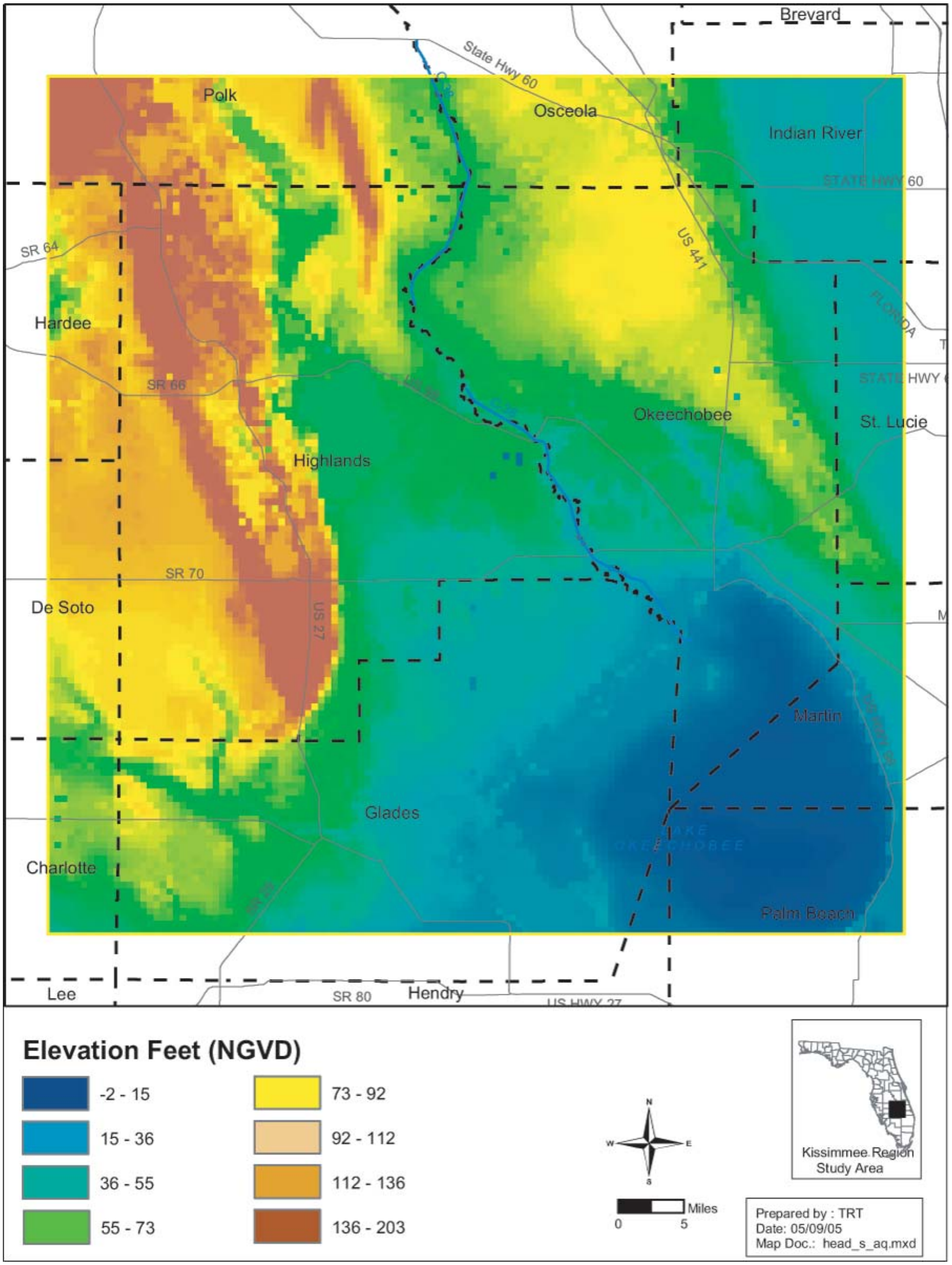

Figure 50. Starting Heads for the Surficial Aquifer Layer.

Layers 2 and 3

The average 1995 potentiometric surface for the Floridan Aquifer System varied from the observation points in the Floridan Aquifer System. Using all points from the contours from the Average 1995 Potentiometric Surface Map and all the observation points from the Floridan Aquifer System, the Inverse Distance Weighting function was applied in ArcGIS (Spatial Analysis) to create a new grid with starting heads for the Floridan Aquifer layers (**Figure 51**).

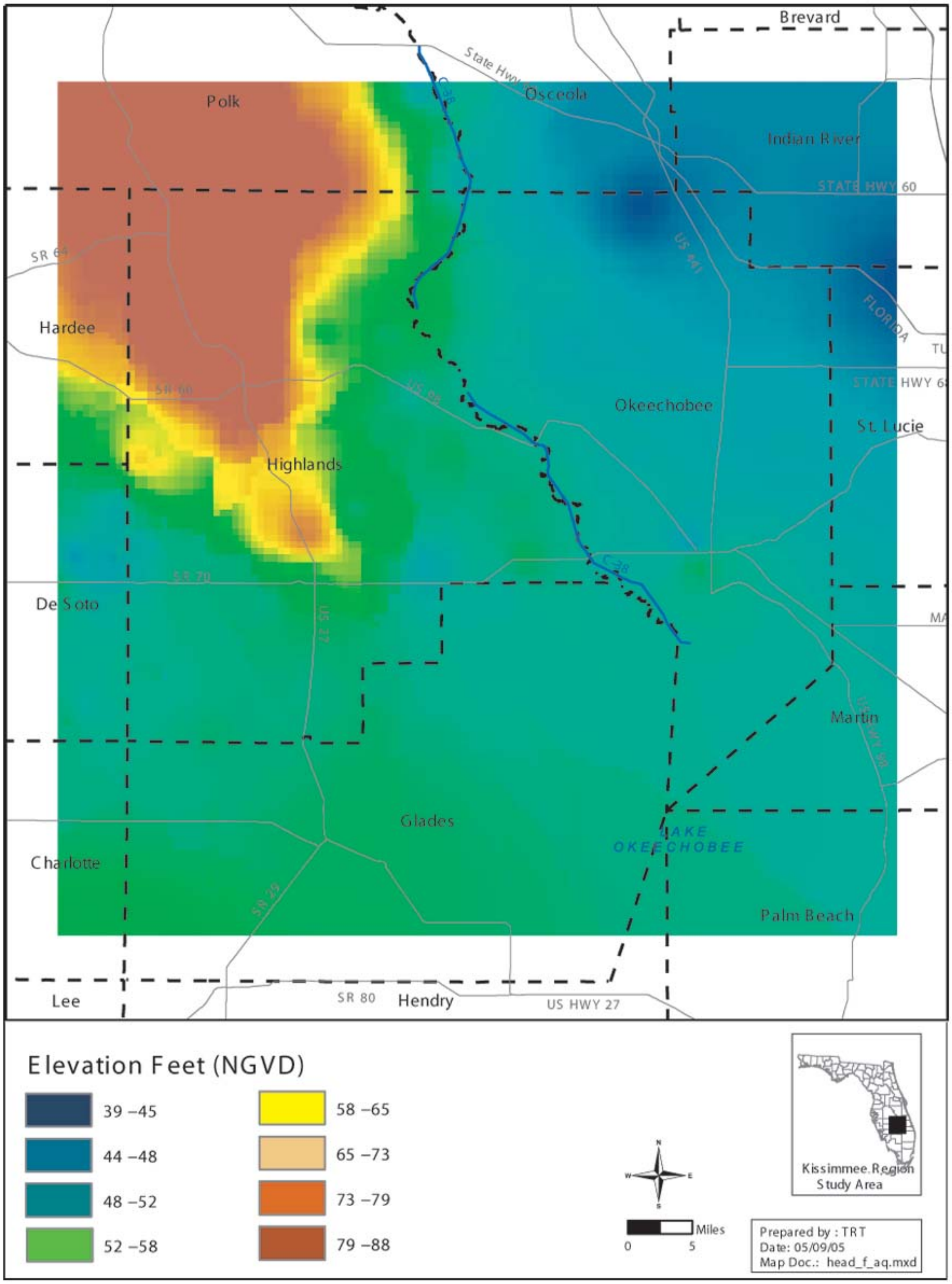

Figure 51. Starting Heads for the Floridan Aquifer Layers.

Vertical Conductance (Vcont)

Within the MODFLOW model, vertical flow between layers is controlled by the vertical conductance coefficient (Vcont), which is a composite term expressed in units of 1/day. Vcont is an expression of the vertical conductivity in confining unit and the thickness of confining unit in that model cell (McDonald and Harbaugh 1988). It is calculated for the two nodes located at vertically adjacent hydrogeologic units (i.e., layers) using the equation (McDonald and Harbaugh 1988):

$$\mathrm{V}_{CONT} = \frac{1}{\frac{\Delta z_u / 2}{K_{zu}} + \frac{\Delta z_c}{K_{zc}} \frac{\Delta z_l / 2}{K_{zl}}} \qquad \text{(Equation 1)}$$

Here, z_u and z_l are the thickness of the upper and lower layers (ft), z_c is the thickness of the confining unit (ft), K_{zu} and K_{zl} are the horizontal hydraulic conductivities for the upper and lower layers (ft/day) and Kz_c is the hydraulic conductivity for the confining unit.

When Kz_c is much smaller than K_{zu} or K_{zl}, then the terms using these values are negligible and Vcont becomes:

$$\mathrm{V}_{CONT} = \frac{1}{\frac{\Delta z_c}{K_{zc}}} = \frac{K_{zc}}{\Delta z_c}$$

The model area had very few hydraulic conductivity data for in the confining zones. The Vcont values for the Intermediate Semi-Confining Unit (**Figure 52**) needed to be adjusted as a calibration factor. The model was divided into zones to determine the appropriate Vcont values. For starting points, the Vcont values shown in Sepulveda, N 2002 were used. In some areas along Lake Wales Ridge, the Intermediate Confining Unit is breached by sinkholes. This is expressed as high Vcont values. In other areas, the unit is nearly completely confining. When Vcont values were too low, the water levels in the Surficial Aquifer System would rise to unacceptable levels and the water levels in the Upper Floridan Aquifer would be too low. The opposite would occur when Vcont values were too high. In areas where artesian conditions exist, the flow through the Intermediate Semi-Confining Unit is from Layer 2 to Layer 1. The Vcont values range from 0.0000001 (feet/day/feet) to 0.006 (feet/day/feet). The average is 0.0002 (feet/day/feet). Since the Vcont is a function of K_z, the calibrated Kz values can be calculated by multiplying by the layer thickness. The average K_z is 0.0046 ft/day. **Figure 53** shows the calibrated vertical hydraulic conductivity for the Intermediate Confining Unit.

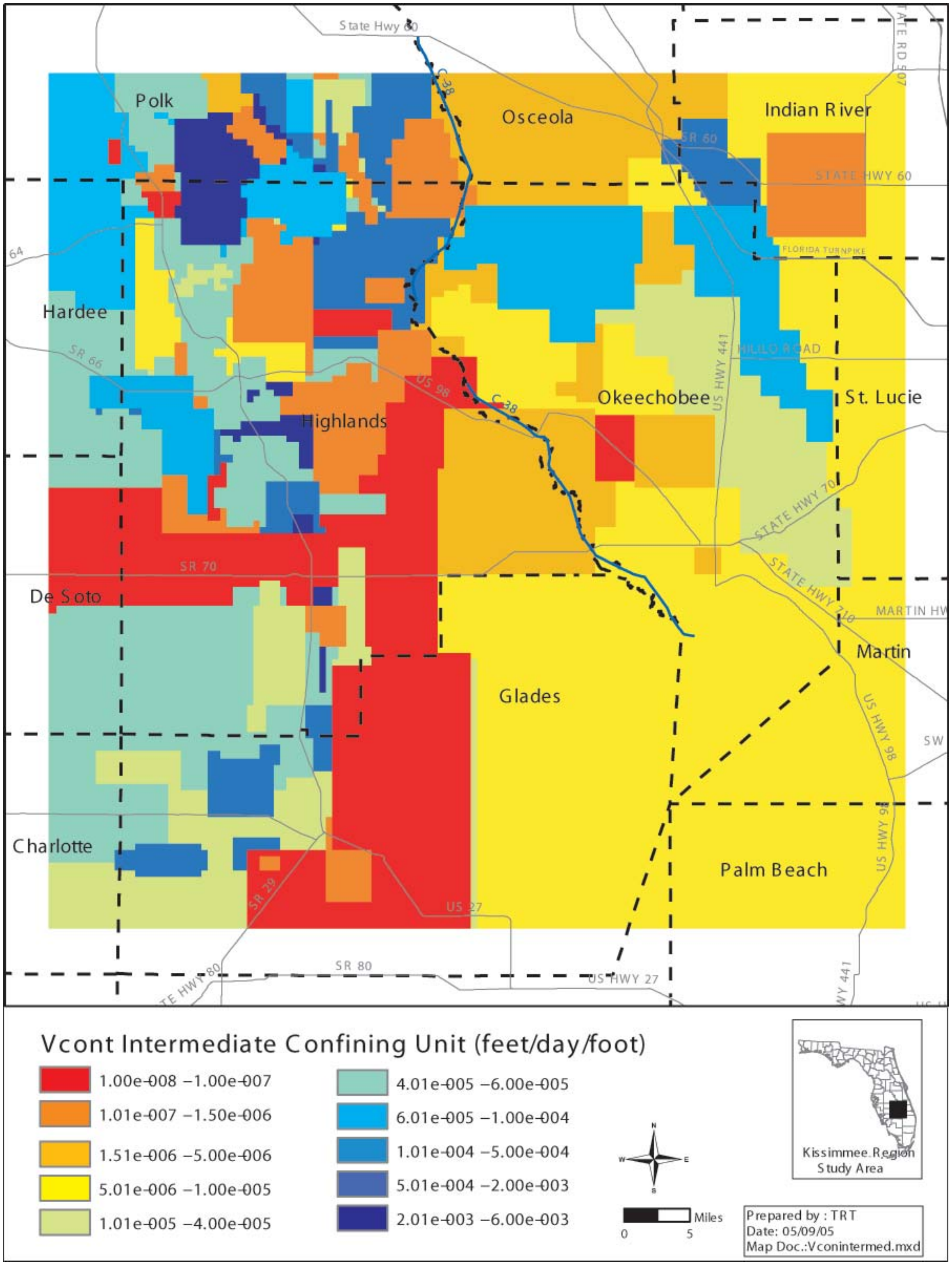

Figure 52. Calibrated Vcont Values for the Intermediate Confining Unit.

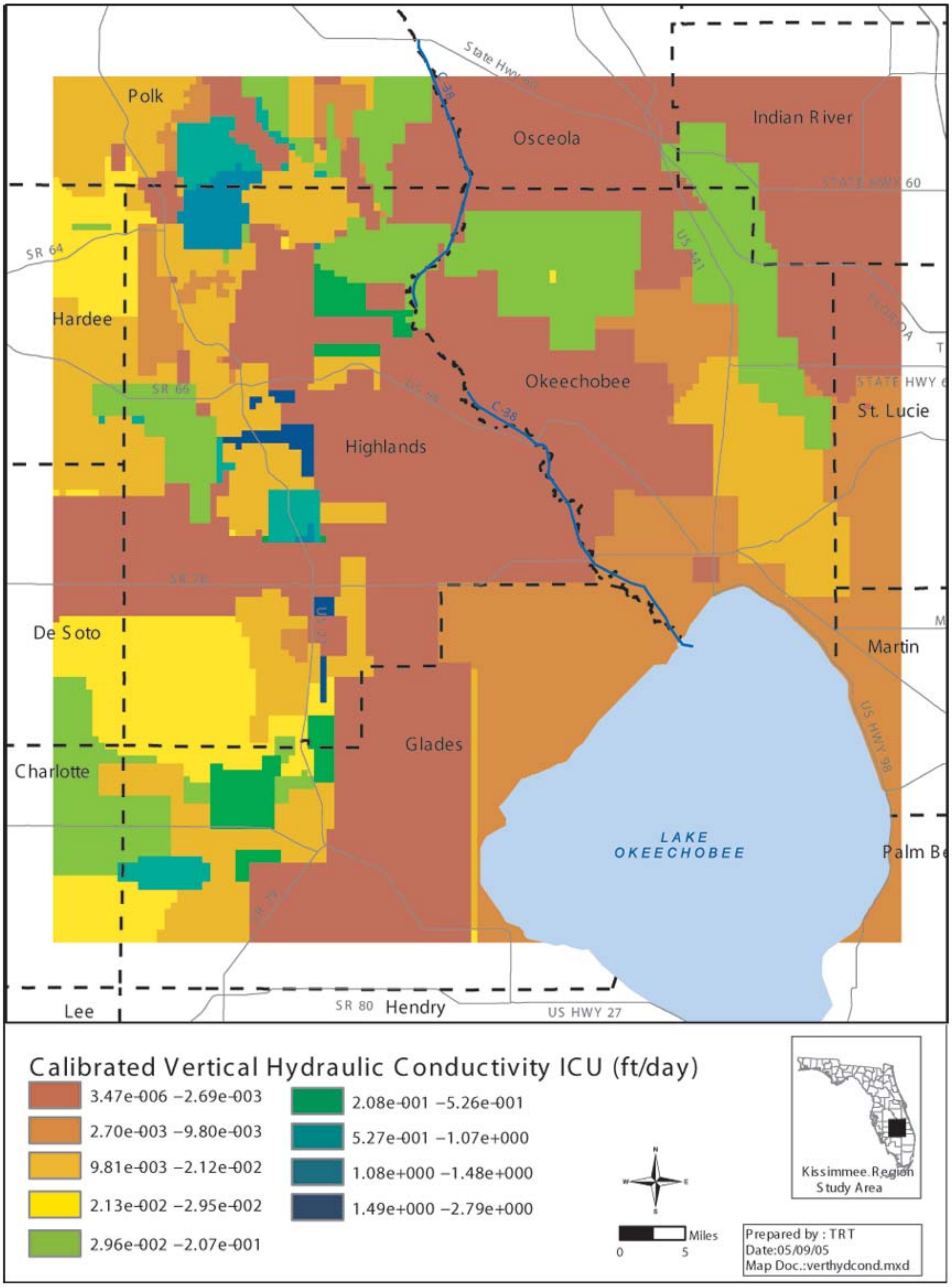

Figure 53. Calibrated Vertical Hydraulic Conductivity for the Intermediate Confining Unit.

For the Middle Confining Unit 1 (**Figure 54**), Kzc was assumed to be 1 and was divided by the thickness of the Middle Confining Unit 1 to obtain an array for Vcont23. For the Middle Confining Unit 2, Kzc was assumed to be 0.5 and it was divided by the thickness of the Middle Confining Unit 2 to obtain an array for Vcont34. **Figure 55** presents the estimated Vcont values for the Middle Confining Unit 2.

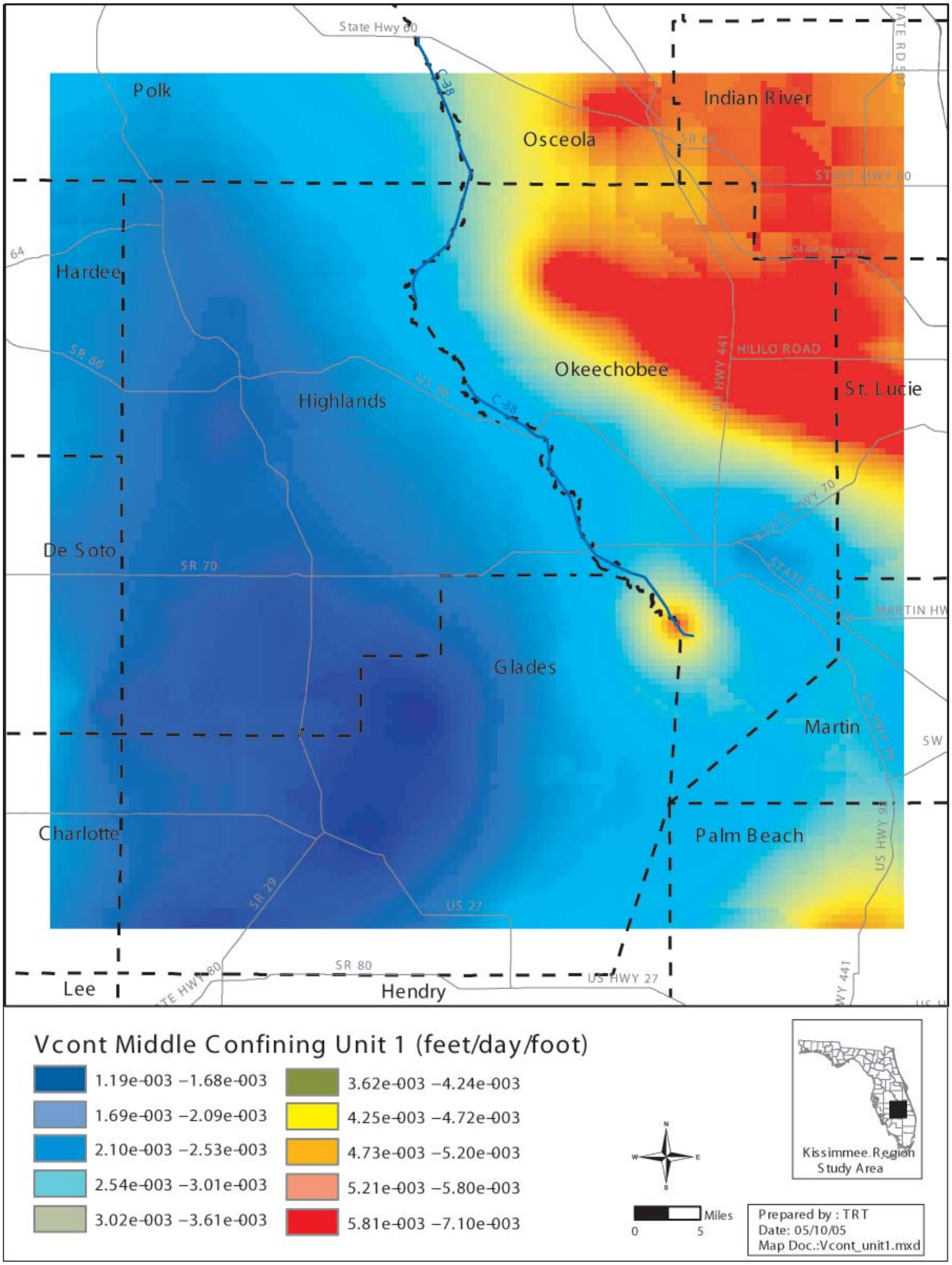

Figure 54. Estimated Vcont Values for the Middle Confining Unit 1.

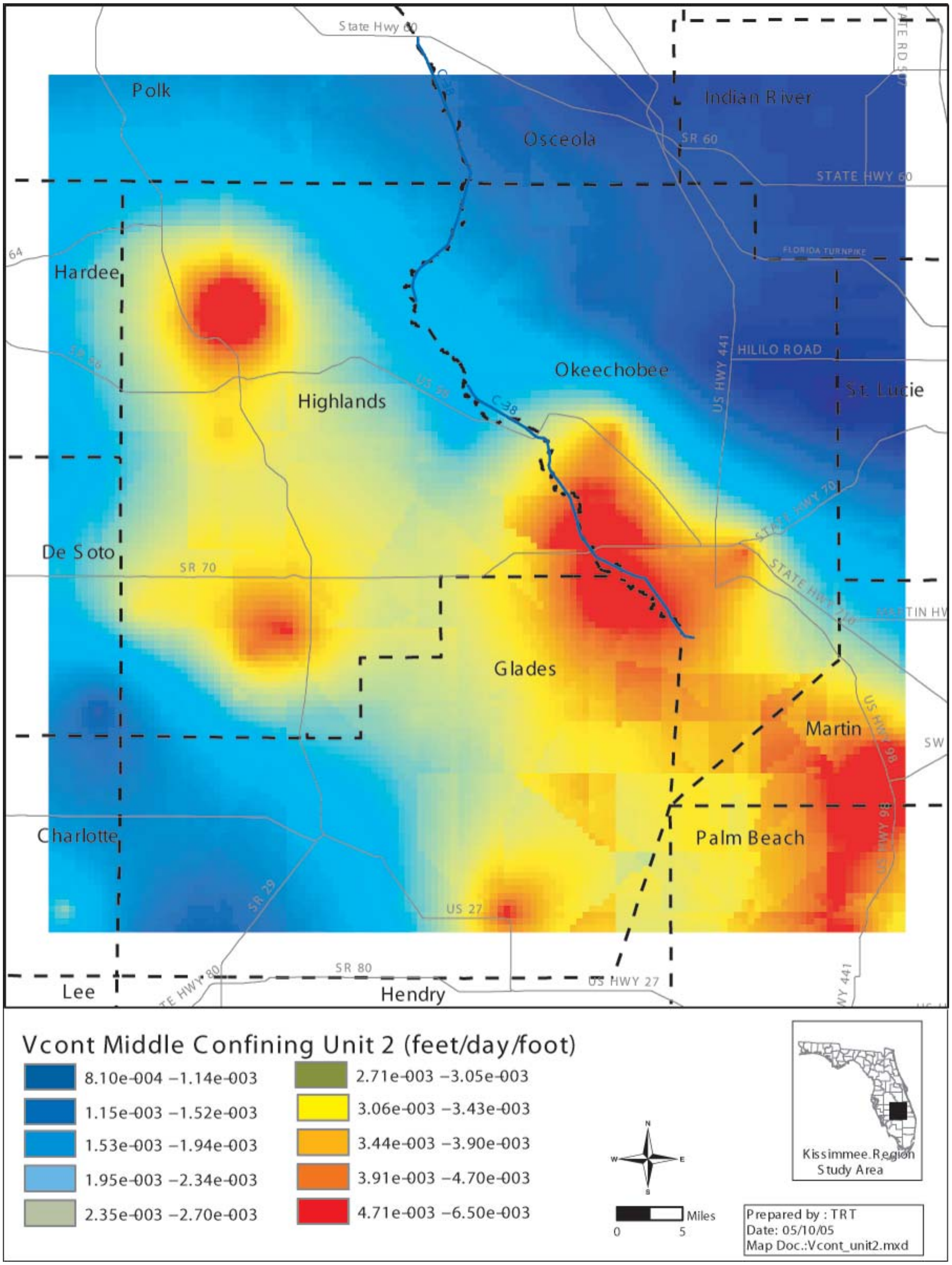

Figure 55. Estimated Vcont Values for the Middle Confining Unit 2.

River Package

Lakes, rivers, streams and canals (**Figure 56**) were represented in the model using the MODFLOW River package. The River package requires the row and column of each river segment, the stage (water level) in the river, the hydraulic conductance between the aquifer and the stream (C_{riv}) and the bottom elevation of the river (R_{bot}). The river module calculates (Q_{riv}) the discharge rate of the stream in ft^3/day, where $Q_{riv} = C_{riv} (H_{riv} – Hsr)$ for $Hsr > R_{bot}$

$_{\text{and}}$ $Q_{riv} = C_{riv} (H_{riv} – R_{bot})$ for $Hsr <= R_{bot}$

Where

$C_{riv} =$ KvLW/ M.

Where

$H_{riv} =$ The stage in the river.

Hsr = The simulated model head in the cell containing the river reach.

Kv = The vertical hydraulic conductivity of the streambed material ft/day. Initial vertical conductivity was estimated at 0.0864 ft/day, but with calibration, found the discharge rates were too low and raised the K value to 1.73 ft/day for all stream reaches.

L = The length of the river reach in that cell in feet.

W = The width of the river reach in feet.

M = The thickness of the streambed in feet (Assumed to be 1 ft for all the reaches).

The model calibration used average stages for 1995 where available.

Canals

Canal cross sections were obtained from the Design Manuals of the Army Corps of Engineers for the Kissimmee Basin (Region IV). From these manuals, the canal bottom width, bottom elevation and slope were obtained. The top width could be calculated from the other information. The average stages for 1995 were obtained for the structures along the canals and these were applied to the canal segments between the structures.

Rivers

Cross sections are not available for the rivers so the top width of the rivers was estimated by viewing aerial photos (The resolution of the image is 10 meters). If gauges were available along the river, they were used to estimate the stage of the river, otherwise the stage of the river was assumed to be at the surface elevation of that cell and river bottom calculated from any depth information available from the U.S. Geological Survey (USGS) or county Web sites. When depth information was not available, it was estimated between 3 and 5 feet below land surface (bls).

Streams

Streams were added using the National Hydrography Dataset (NHD[1]). The National Hydrography Dataset is a feature-based database, which interconnects and uniquely identifies the stream segments or reaches comprising the nation's surface water drainage system. It is based initially on the content of the USGS 1:100,000-scale Digital Line Graph (DLG) hydrography data, integrated with reach-related information from the U.S. Environmental Protection Agency Reach File Version 3.0 (RF3). More specifically, it contains reach codes for networked features and isolated lakes, flow direction, names, stream level and centerline representations for aerial water bodies. The National Hydrography Dataset also incorporates the National Spatial Data Infrastructure framework criteria set out by the Federal Geographic Data Committee. The steams for the Lower Kissimmee Basin were all estimated to be 25 feet wide and 2 feet deep.

Lakes

Lakes were delineated from the National Hydrography Dataset coverage. All the features labeled as "lakes or ponds" were selected. Due to the presence of numerous lakes within the model area, only those with a surface area greater than 30 acres were included in the model. Lake depths and bathymetric maps were obtained from the following Web sites: University of Florida Institute of Food and Agricultural Sciences (IFAS) LAKEWATCH[2]; the University of South Florida[3]; and Highlands County Soil and Water Conservation District[4]. When actual depth information was not available, Secchi depth readings were used as a starting point to estimate the depth – the water is at least as deep as the Secchi reading. Lake stages were obtained from South Florida Water Management District (SFWMD)[5], Southwest Florida Water Management District (SWFWMD)[6], St. Johns River Water Management District (SJRWMD)[7] and U.S. Geological Survey

[1] NHD http://nhd.usgs.gov/

[2] LAKEWATCH http://lakewatch.ifas.ufl.edu/maplist.htm

[3] Polk County http://www.polk.wateratlas.usf.edu/navigator/

[4] Highlands County http://www.highlandsswcd.org/

[5] SFWMD DBHYDRO http://www.sfwmd.gov/site/index.php?id=38

[6] SWFWMD http://www.swfwmd.state.fl.us/data/

[7] SJRWMD http://www.sjrwmd.com/programs/data.html

(USGS)[8] stage monitors and the previously mentioned Web sites. Many of the lakes are not gauged. When no measured water levels were available, the water levels were estimated based on the water levels in nearby lakes and the surface elevation of the cell/cells containing the lake. If a lake contained multiple cells all the cells, were set to one stage elevation. To calculate C_{riv} for the lakes, the "reach length" was assumed to be the square root of the lake area.

[8] USGS National Water Information System http://nwis.waterdata.usgs.gov/usa/nwis/

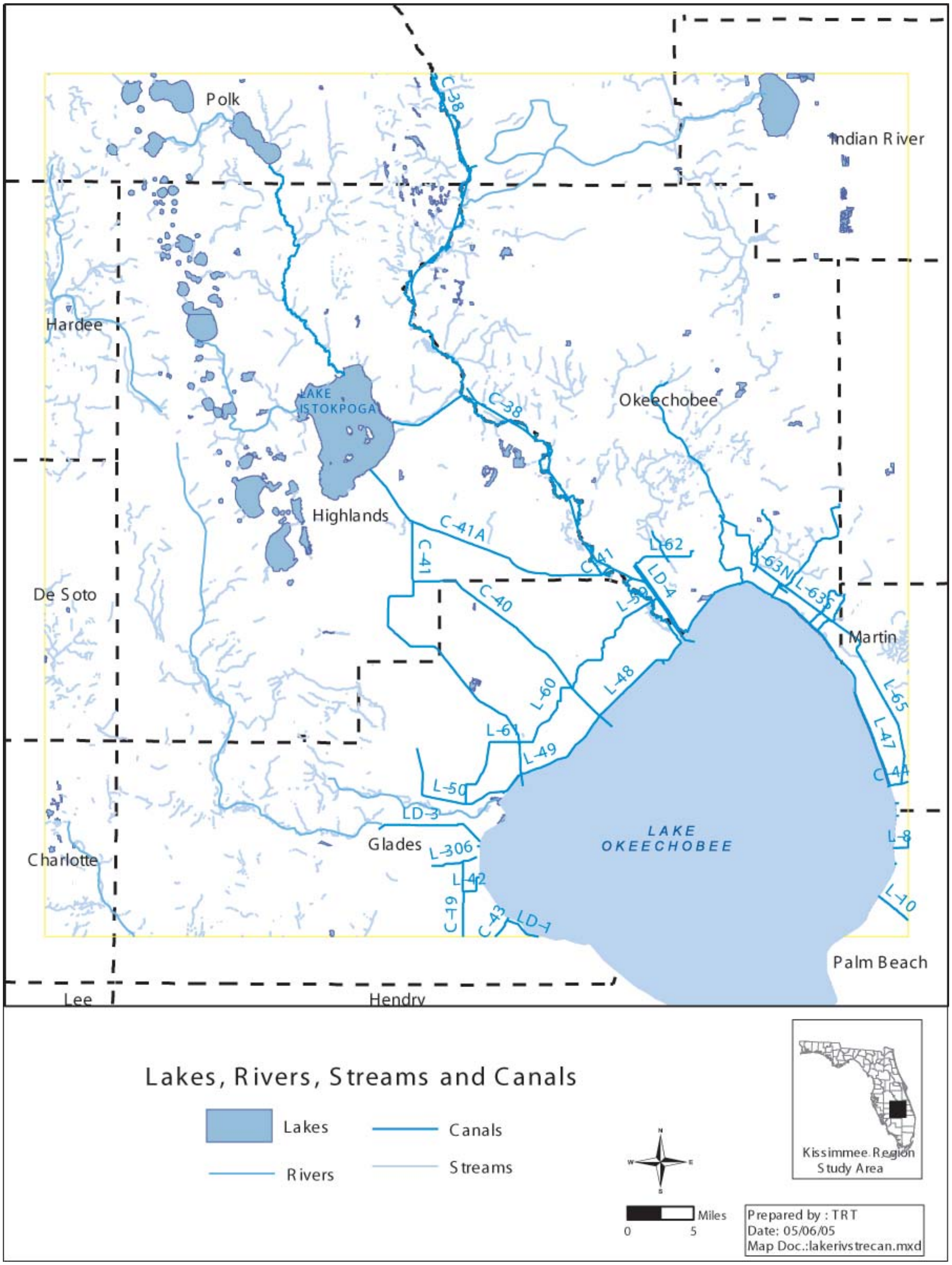

Figure 56. Lakes, Rivers, Streams and Canals.

Drain Package

The MODFLOW Drain module is similar to the Rivers module, but differs in that rivers allow water to flow in and out of the model, while drains only remove water from the system. As long at the head in the cell is above the drain elevation, water will be removed from the cell. Drains (**Figure 57**) require only a drain elevation and the conductance between the drain and the aquifer.

$C_{drain} = KvLW/ M$

Where

Kv = The vertical hydraulic conductivity of the drain material, was assumed to be 0.25 – 0.5 ft/day.

L = The length of the drain reach in that cell in feet.

W = The width of the drain reach in feet.

M = The thickness of the streambed in feet (Assumed to be 1 ft for all the reaches).

The drains were delineated from the National Hydrography Dataset coverage. All the features labeled as “ditches or canals” were added. These drains are mainly irrigation ditches. The width of the drains was estimated from aerial photos. The numbers prevented review of each ditch, but were estimated by sampling the aerial photos of ditches in area. The slope for all the ditches was assumed to be 1:4 since ditches tend to wide and shallow, thus the depth was assumed to be ¼ of the width. The stages were set to the surface elevation and the drain elevation was set to x feet below the surface depending on estimated depth.

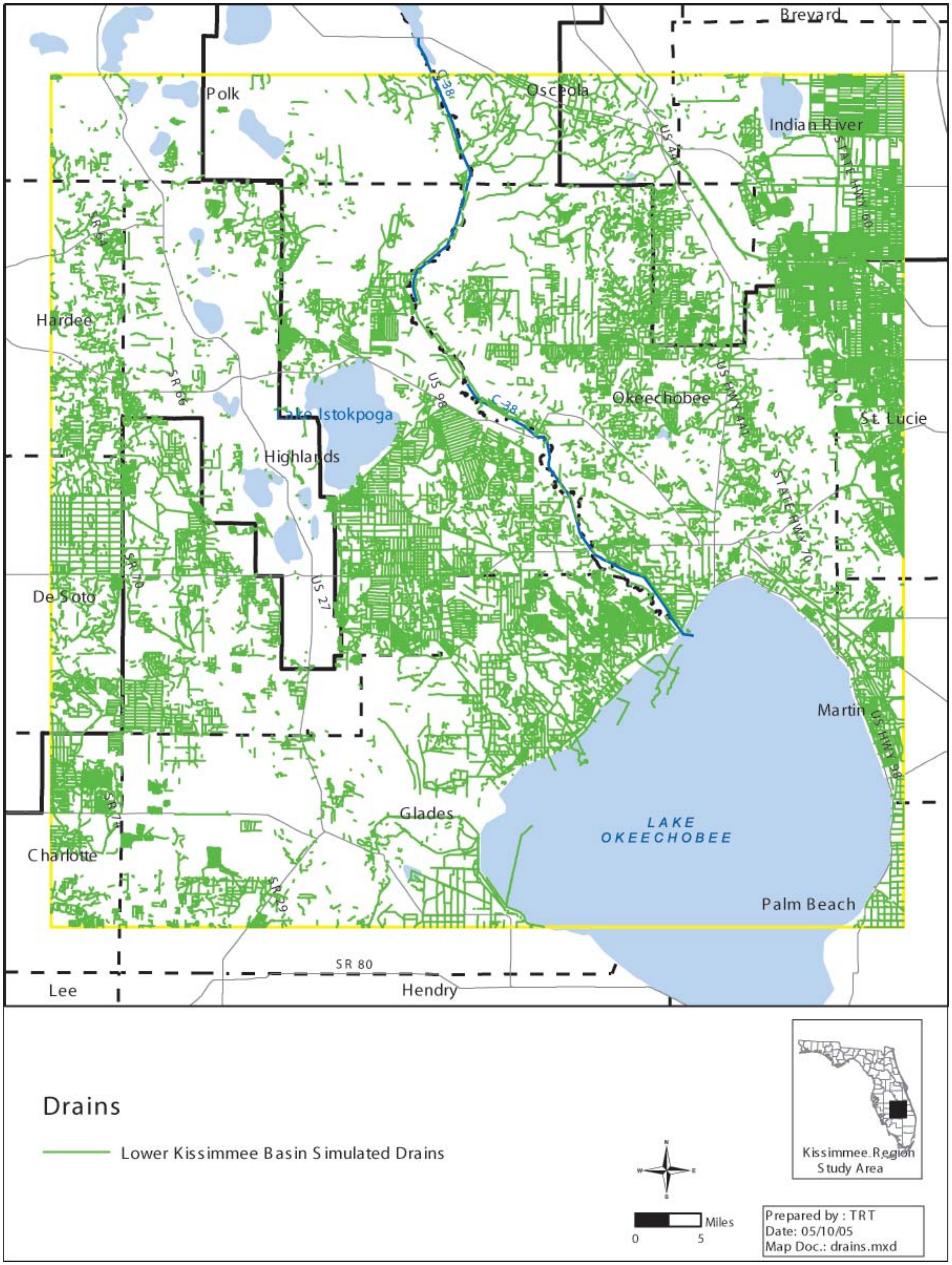

Figure 57. Drains.

Evapotranspiration (ET) Package

The evapotranspiration package includes the following input data:

1. An evapotranspiration surface array depicting the elevations above which evapotranspiration from the water table occurs at a maximum rate.
2. An array of extinction depths that represent the water depths below the evapotranspiration surface where evapotranspiration rates from the water table become negligible.
3. An array of maximum potential evapotranspiration rates.

MODFLOW uses the aforementioned arrays and estimates the evapotranspiration depth for the saturated zone. The MODFLOW package uses ground surface and an evapotranspiration extinction depth term to simulate the diminishing ability of vegetation to use water at increasing depth. In MODFLOW, the following assumptions are applied (McDonald and Harbaugh 1988):

When the water table is above the evapotranspiration surface, the evapotranspiration losses from the water table occurs at the maximum rate (evapotranspiration rate=maximum evapotranspiration rate). When the water table is below the extinction depth, no evapotranspiration occurs from the evapotranspiration surface. (ET Rate=0)

Evapotranspiration (**Figure 58**) from the water table varies linearly between the maximum (at the evapotranspiration surface) and minimum limits (at the extinction depth see definition next section)

The evapotranspiration surface array was based on topography. The evapotranspiration surface was set land surface elevation with the exception of Avon Park Ridge were set to 10 feet above land surface.

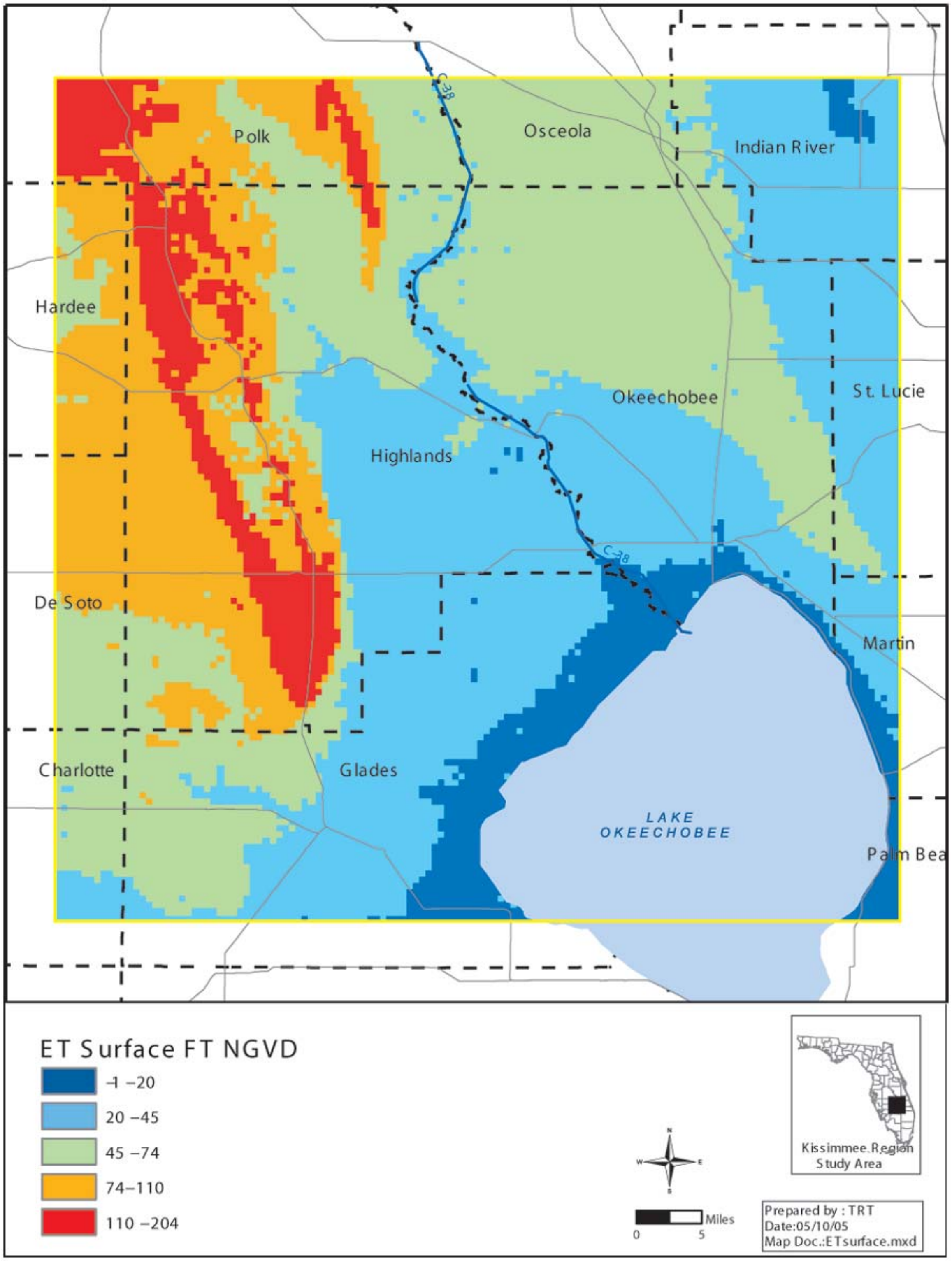

Figure 58. Evapotranspiration Surface (ft).

Extinction Depth

The extinction depth (**Figure 59**) array was based on shallow and deep root zone depths. As outlined in Restrepo and Giddings (1994), a daily water balance was conducted on each unique combination of land cover and soil type. A corresponding maximum evapotranspiration rate was assigned to each of these combinations. The deepest extinction depths correspond to lake areas and of surface water bodies. The extinction depths in the lakes and water bodies was set to 20 feet, essentially assuring that in these areas the maximum evapotranspiration rate will always be applied. (Lake Okeechobee is inactive in Layer 1 so the extinction depths were not used in that area.)

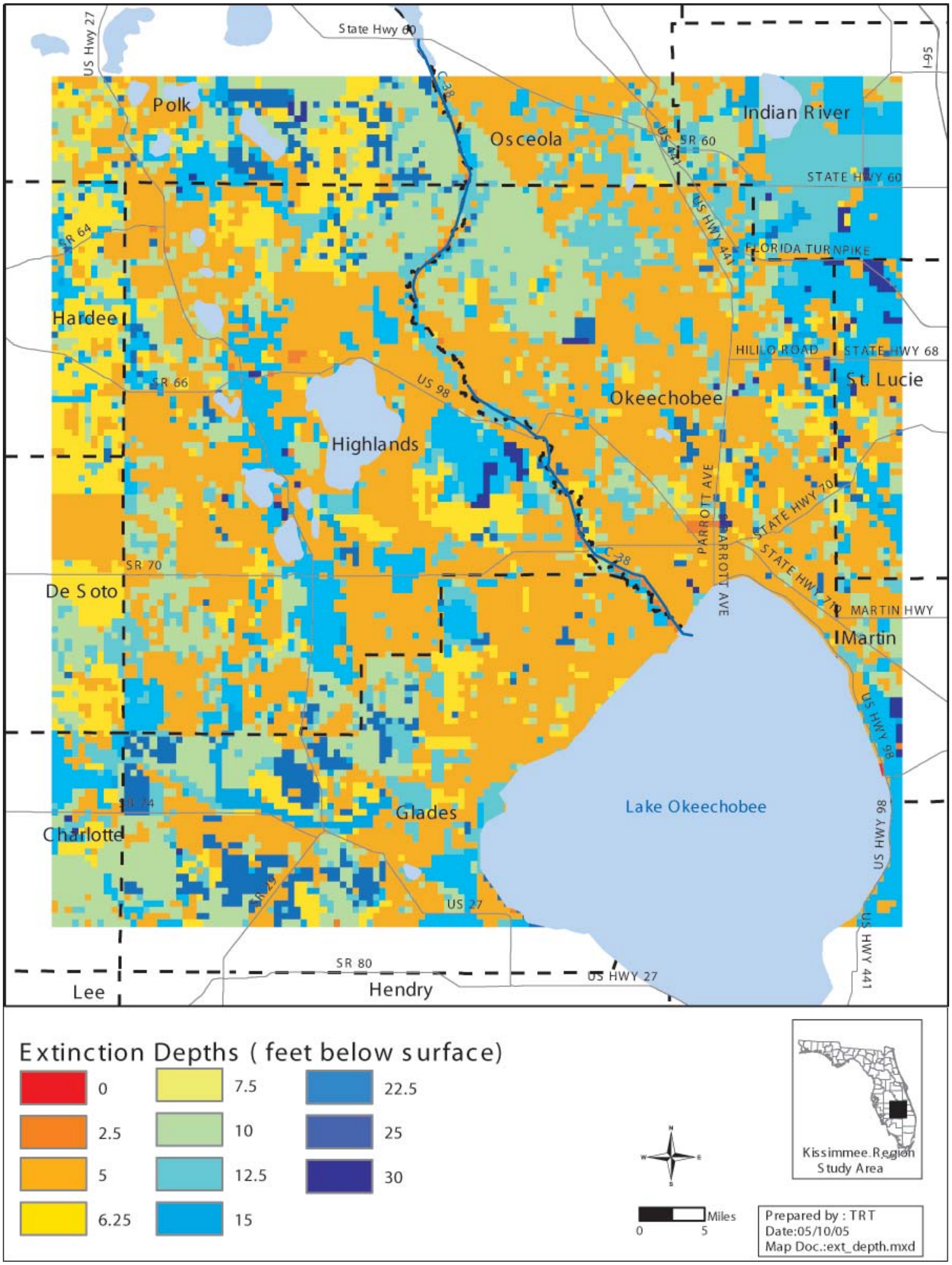

Figure 59. Extinction Depths.

Reference Evapotranspiration

The potential reference evapotranspiration was calculated by the “South Florida Water Management District Simple Method” using *wet marsh reference evapotranspiration*, as described in Irizarry-Ortiz (2003). The SFWMD Simple Method was developed as a modification to the Penman-Monteith method due to the lack of a comprehensive meteorological database for south Florida. The Penman-Monteith requires input from many meteorological variables, which are hard to measure or estimate. The SFWMD Simple Method (Equation 2) was developed to be a simpler yet equally accurate method for estimating the potential evapotranspiration for wetlands marsh Irizarry-Ortiz (2003).

$$ET_p = \frac{K_1 * R_s}{\lambda} \qquad \text{(Equation 2)}$$

ETp: Wet marsh potential evapotranspiration [mm d-1].

K1: Coefficient (0.53 for mixed marsh, open water and shallow lakes).

Rs: Solar radiation received at the land surface [MJ m-2 d-1].

λ: Latent heat of evaporation [MJ kg-1].

In order to calculate the wet marsh reference evapotranspiration, the solar radiation at land surface needed to be calculated from the average minimum and maximum temperatures. Daily wet marsh potential evapotranspiration values were calculated for years 1965–2001, and then only the values for 1995 were used to calculate the daily maximum potential evapotranspiration rate for each evapotranspiration station. The *wet marsh reference evapotranspiration* was calculated with the aid of the ETCALC program built into an Excel spreadsheet. The program required daily temperature data with no gap periods. Missing temperature data were estimated by comparing the temperature of nearby stations. For example the temperatures at Avon Park were compared to those at Wauchula (west of model boundary). See **Figure 60**.

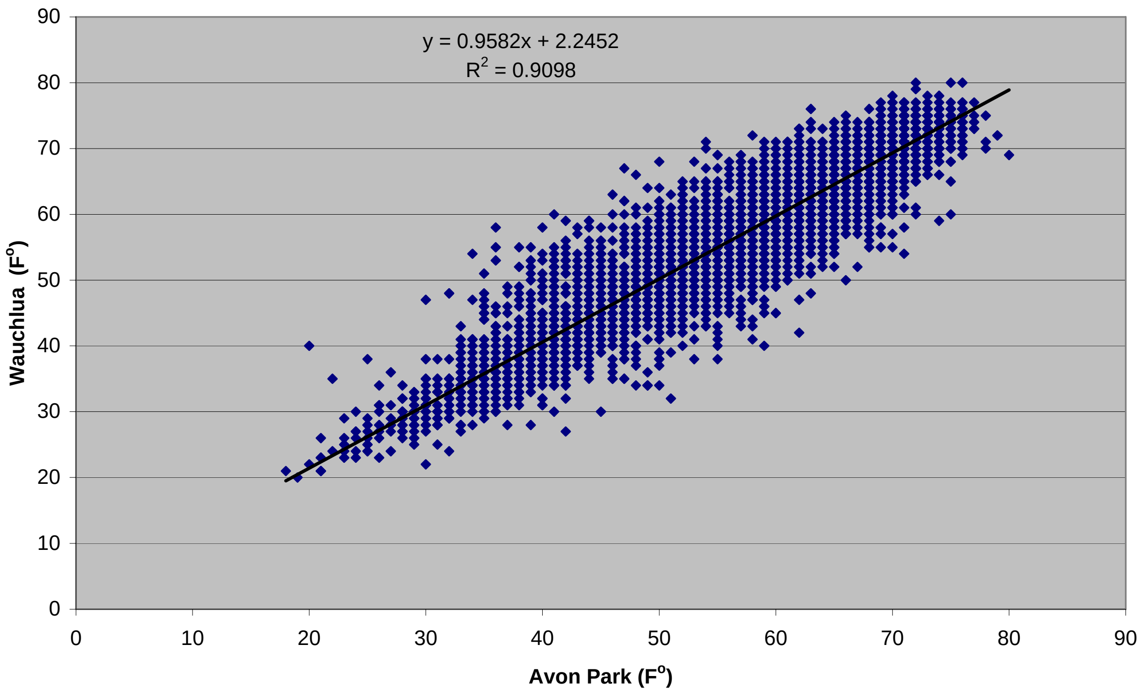

Figure 60. Comparison of Temperatures in Wauchula and Avon Park.

The ETCALC also required the average potential evapotranspiration for a given longitude and latitude based on Visher and Hughes, 1969.

$$R_s = \tau R_a = R_a K_r (T_{\max} - T_{\min})^{0.5} + B$$

Where

Rs: Solar radiation received at the land surface [MJ m-2 d-1 or W/m2] (MJ is micro-joules, W is Watts microjoules * square meters per day or watts per square meter).

τ: Atmospheric transmissivity.

Kr: Empirical coefficient.

Tmax: Mean daily maximum temperature over the period of interest [^{o}C].

Tmin: Mean daily minimum temperature over the period of interest [^{o}C].

Ra: Extraterrestrial solar radiation [MJ m-2 d-1 or W/m2].

B: Empirical term [MJ m-2 d-1 or W/m2].

K_r is empirical coefficient, which is used in the ETCALC program. For the model area the Kr was assumed to be equal to 0.22. The potential evapotranspiration for wetlands marsh was calculated for each National and Oceanographic and Atmospheric Administration (NOAA) station in the model vicinity. ETCALC program required only the following parameters from the end user – temperatures, Kr, the latitude and longitude of the evapotranspiration station and B. B is an empirical number adjusted for each station. Various numbers were tried to reach a resulting average annual ETp close to 50 inches/year.

Figure 61 shows the evaporation station locations and Thiessen polygons.

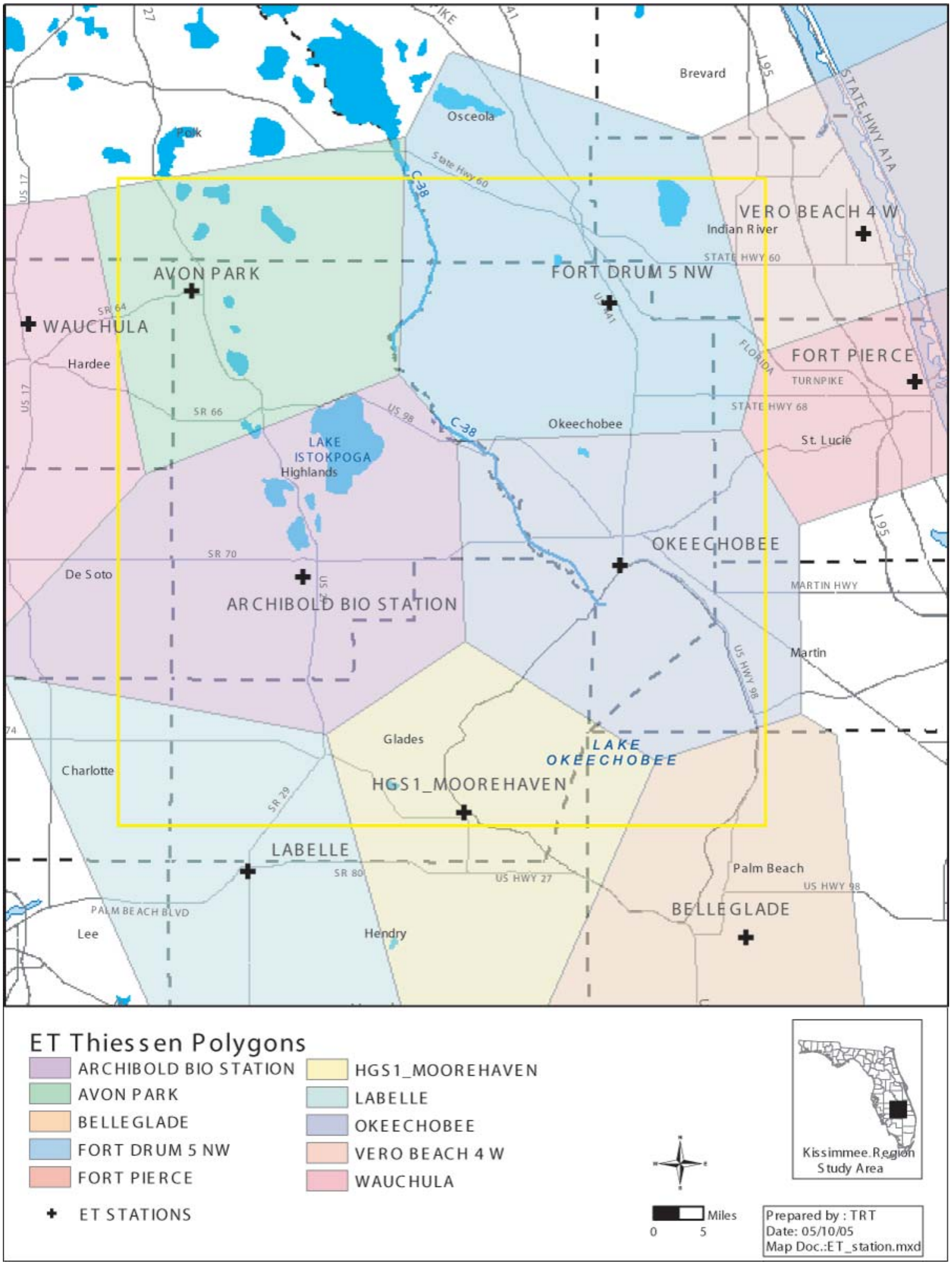

Figure 61. Evapotranspiration Station Locations and Thiessen Polygons.

Maximum Potential Evapotranspiration Rate

Potential evapotranspiration (ET) is defined as “the rate at which water, if available, would be removed from saturated soil in the form of latent heat per unit area or the equivalent depth of water (Giddings and Restrepo 1995).

The maximum potential saturated evapotranspiration rate (**Figure 62**) is estimated as:

$ET_{saturated\text{-}max} = ETp - ET_{UNSATURATED}$.

ETp is the potential ET for each crop.

ETp = kc x ETr.

Kc is a coefficient for each crop or land use type. The Kc is modified to the growth season of each crop. The Agricultural Field Scale Irrigation Requirements Simulation (AFSIRS), which was developed by Smajstrla (1990) to estimate crop irrigation demands for crops in South Florida and assigned a Kc for each crop.

ETr is the reference ET Depth for Wetland Marsh.

The ET of the unsaturated zone approaches zero because the water in the unsaturated zone is used by the plants and crops, if the water in the unsaturated zone is insufficient for the plant, then it uses more water from the saturated zone (Restrepo and Giddings 1994).

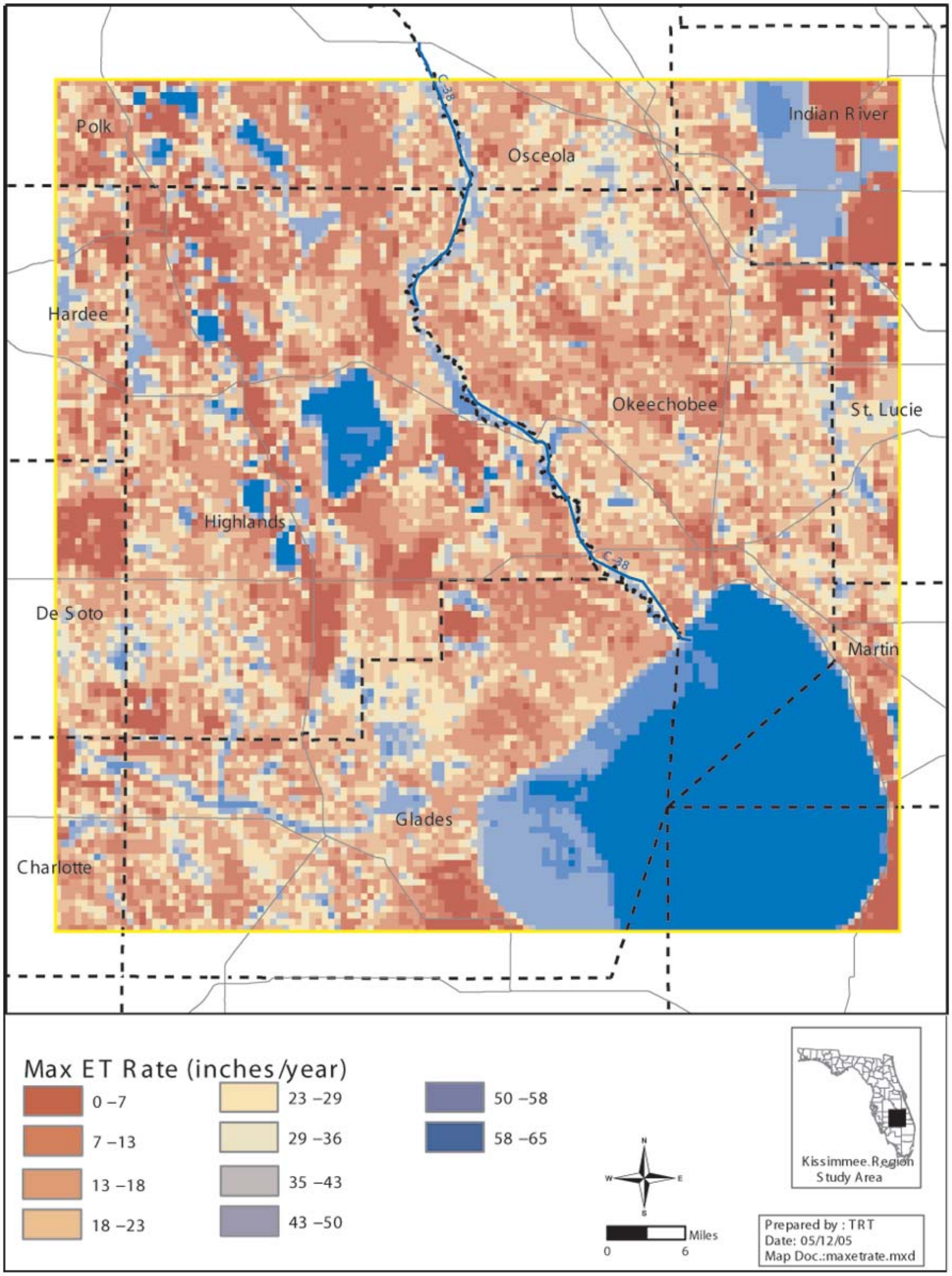

Figure 62. Max Potential Evapotranspiration Rate.

Recharge

In addition to estimating the maximum potential evapotranspiration rate, the ET-RECHARGE program (Giddings and Restrepo 1995) calculates the crop irrigation demands and the recharge into the Surficial Aquifer System (**Figure 63**). The program uses ArcGIS coverages of land use/land cover, soils, rainfall, evapotranspiration and irrigation demand to estimate the recharge in each model cell. The basic water budget for AFSIRS as stated in (Giddings and Restrepo 1995).

STO = RAIN +NIRR – DRAIN – RUNOFF – ET.

STO is the change in soil water storage, RAIN is the rainfall, NIRR is the net water irrigation requirement, DRAIN is Drainage, RUNOFF is the surface water runoff and ET is the evapotranspiration.

The AFSIRS program combines RUNOFF and DRAIN into one drainage component.

The daily water balance analysis yields the amount of recharge to the water table, which is input to the model.

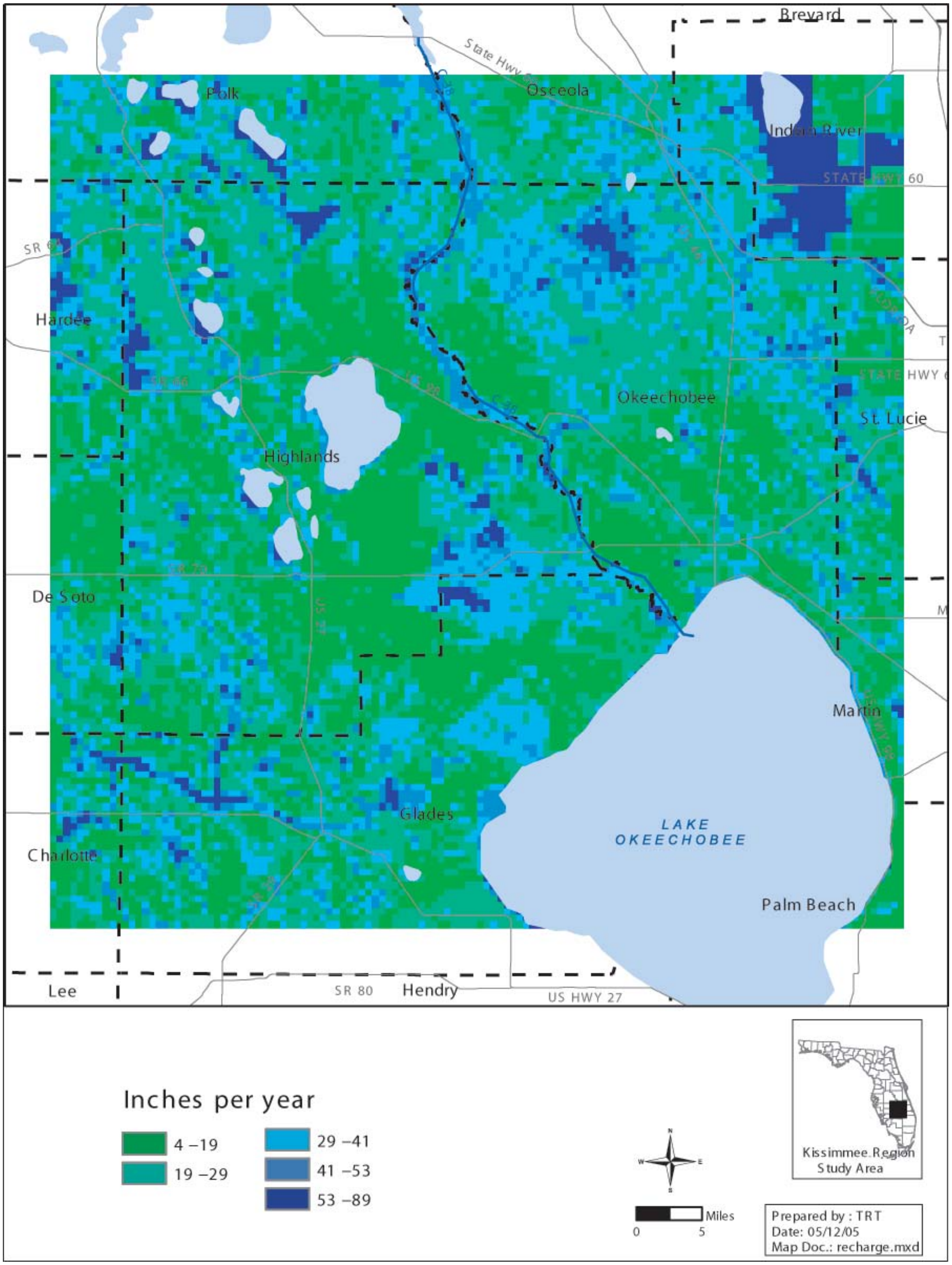

Figure 63. Recharge in the Model Area.

Rain

The average annual rainfall in the model area is 55 inches.

There are more rain stations available than weather stations, so the area was divided into more Thiessen polygons. The average daily 1995 rainfall values were assigned to each Thiessen polygon, and used in with the AFSIRS program to estimate recharge. Only rainfall stations having over 360 days of data for 1995 were used.

Figure 64 shows the rainfall station location and Thiessen polygons. **Figure 65** presents the average 1995 rainfall by station. **Table 14** shows the average 1995 rainfall for each station.

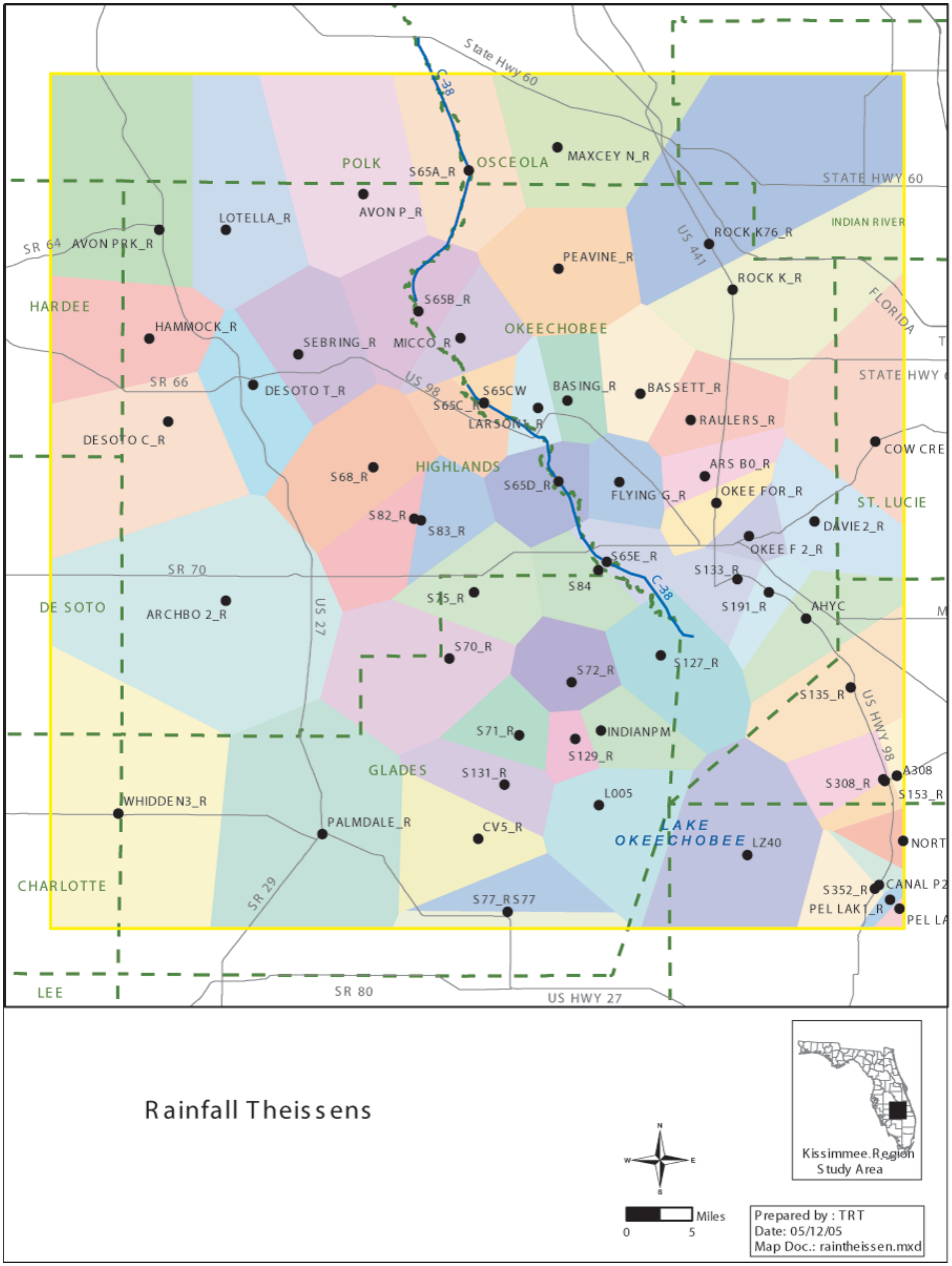

Figure 64. Rainfall Stations and Thiessen Polygons.

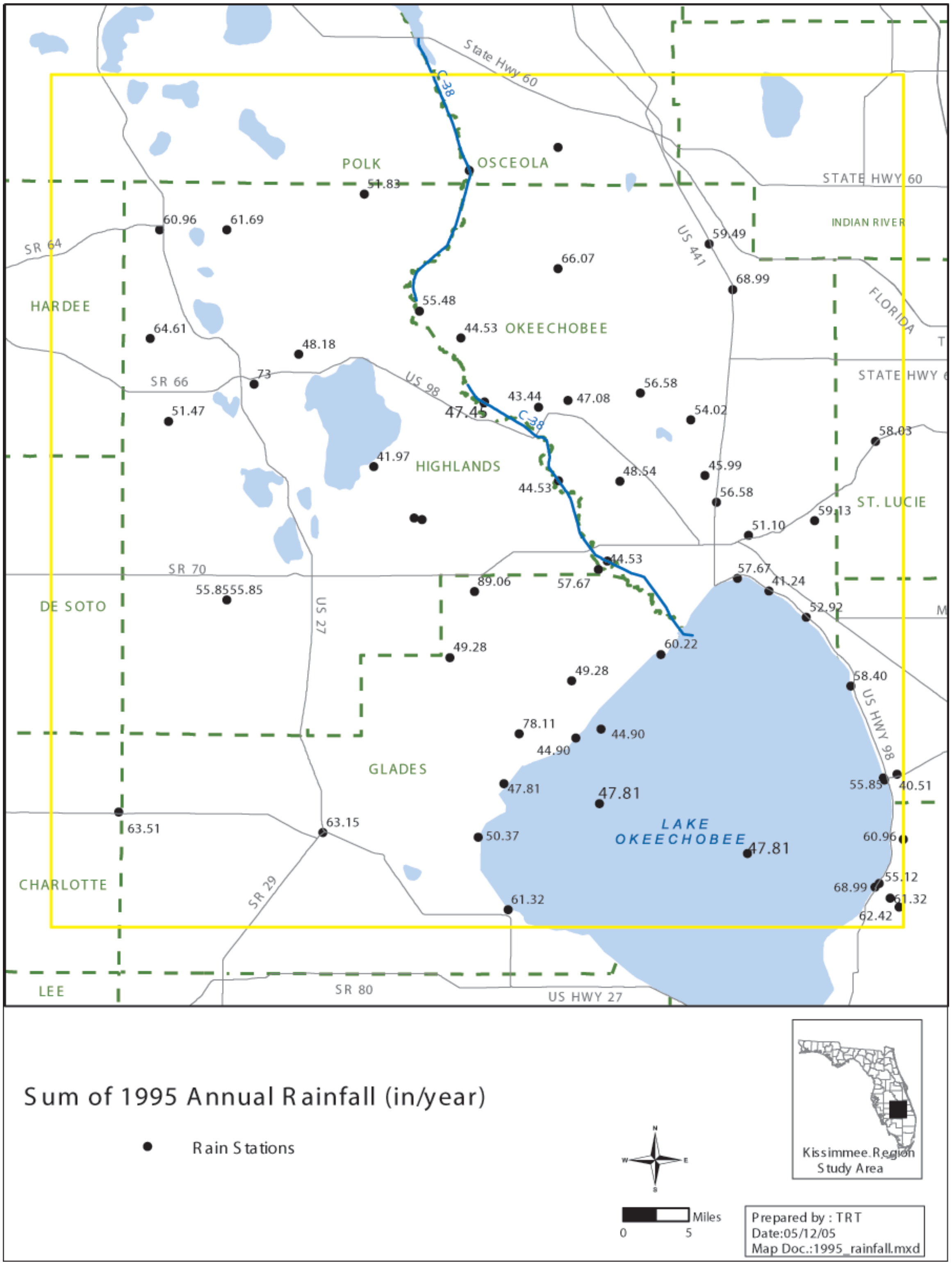

Figure 65. Average 1995 Rainfall by Station.

Table 14. Rainfall Stations and Average 1995 Daily Rain.

Station	DBKey	Average 1995 Rain	Sum Annual 1995 Rain
ARCHBO 2_R	16604	0.15	55.93
ARS B0_R	15582	0.13	45.87
AVON P_R	05854	0.14	51.68
BASING_R	05857	0.15	56.10
BASSETT_R	15577	0.15	56.53
DAVIE2_R	16192	0.16	59.25
DESOTO T_R	06096	0.20	72.62
FLYING G_R	07507	0.13	48.45
LOTELLA_R	05853	0.17	61.63
MAXCEY N_R	05871	0.13	48.75
MICCO_R	05856	0.12	44.51
OKEE F 2_R	16285	0.14	51.08
OKEE F 2_R	16697	0.14	51.08
OKEE FOR_R	06102	0.15	56.23
PEAVINE_R	05858	0.18	66.12
ROCK K_R	05844	0.19	69.06
ROCK K76_R	05866	0.16	59.37
S133_R	05845	0.16	57.75
S133_R	16576	0.16	57.75
S191_R	16669	0.11	41.22
S65A_R	05981	0.14	52.10
S65A_R	16572	0.14	52.10
S65B_R	16282	0.15	55.55
S65B_R	16620	0.15	55.55
S65C_R	06024	0.12	43.29
S65C_R	16657	0.12	43.29

Table 14. Rainfall Stations and Average 1995 Daily Rain (Continued).

Station	DBKey	Average 1995 Rain	Sum Annual 1995 Rain
S65CW	15473	0.13	47.46
S65D_R	16281	0.15	56.03
S65D_R	16658	0.15	56.03
S65E_R	16280	0.12	44.37
S65E_R	16621	0.12	44.37
S68_R	16654	0.12	42.10
S82_R	16655	0.11	40.92
S83_R	16656	0.20	71.28
SEBRING_R	05855	0.13	48.32

Soils

There are over 800 types of soils in south Florida. The U.S. Department of Agriculture (USDA) analyzed and numbered the soils in each county individually[9]. Each county has a unique set of Muid soil numbers, beginning with a county code, and then a soil number (numbers change by county, or year soil survey conducted) and a map unit name, which describes the soil. Using the USDA Soil Conservation Service's (SCS) Soil Surveys for each county, each Muid or map unit name was matched to a South Florida Soil Number. The Muid numbers were linked to the "Soil Survey Geographic" (SSURGO) soil coverage. This layer was derived from the soil surveys developed over many years by the U.S. Department of Agriculture, Soil Conservation Service (SCS), now called the Natural Resources Conservation Service (NRCS). These data are the highest resolution soil data available from the NRCS. The maps have a level of detail comparable with 7.5' USGS topography quads or National Wetlands Inventory (NWI) wetlands maps. The ET-RECHARGE program uses a file, which groups the soils by their properties and assigns a "South Florida Soil Number" to each soil group. The properties include the number of soil horizons, the depth in inches of each horizon and the water capacity of that horizon. The polygons for the 800 soil types used in model are too detailed to display here. The STATSGO soils[10] were also developed by the NRCS. The STATSGO data are a generalization of the SSURGO data. The SSURGO data for the SFWMD were also generalized for important soils within the District. The SFWMD generalization is more detailed than the STATSGO data, but less detailed than the SSURGO data. This generalization is displayed in **Figure 66**.

[9] Published Soil Surveys for Florida http://soils.usda.gov/survey/printed_surveys/florida.html

[10] STATSGO http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/metadata/fl.html

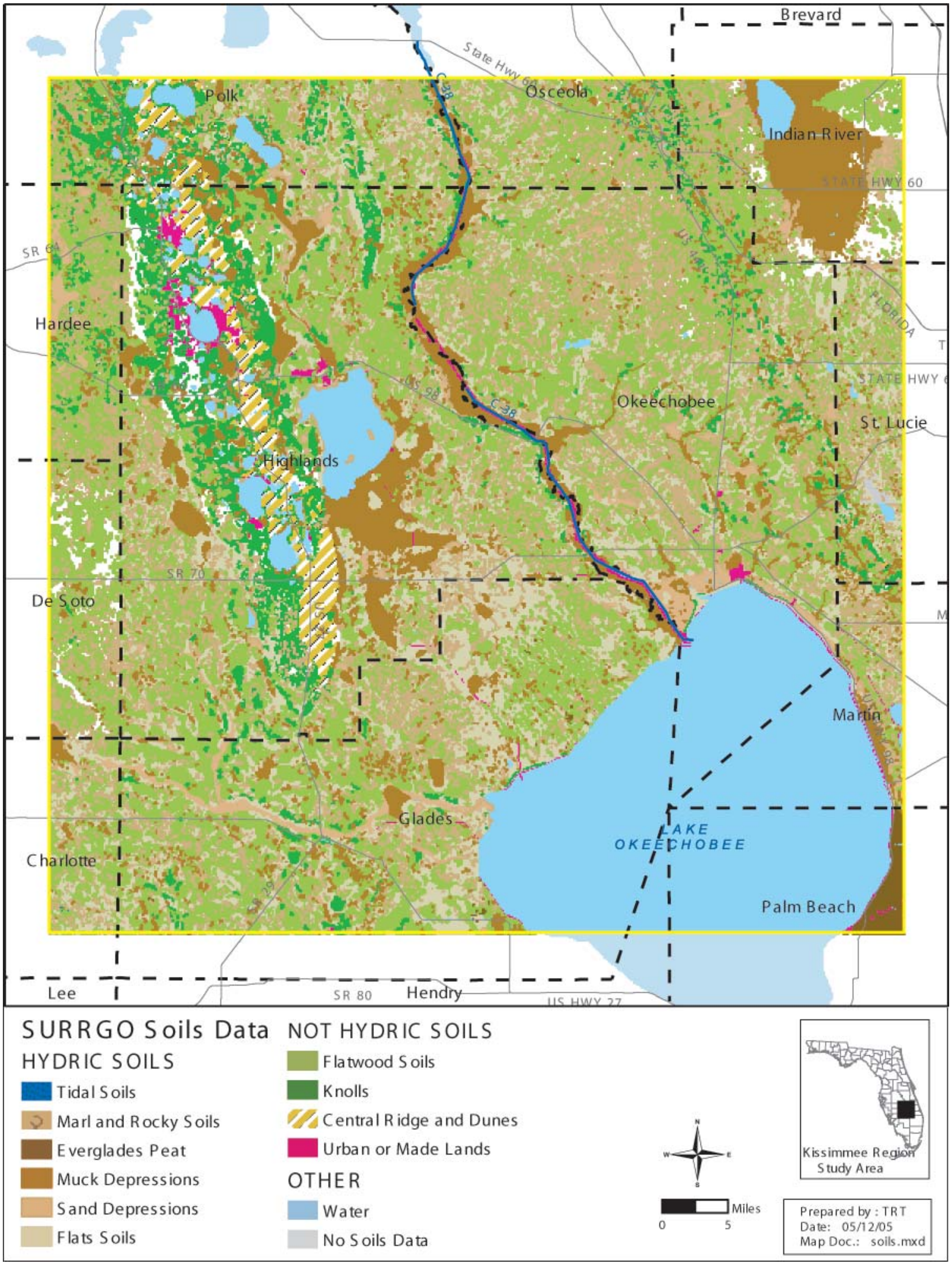

Figure 66. Generalized Soils in the SFWMD.

Land Use

The 1995 land use/land cover maps from the South Florida Water Management District (SFWMD), St. Johns River Water Management District (SJRWMD) and Southwest Florida Management District (SWFWMD) were combined for the model area. The land use/land cover maps were produced by photo interpretation of 1:40,000 USGS NAPP color infrared photography. All three water management districts used a modification of statewide Florida Land Use and Cover Classification System (FLUCCS), which is maintained by the Florida Department of Transportation (FDOT). This modified version uses classes that are mainly at the community level, but also includes a number of species of concern. Modifications and corrections have been made to the map since its creation. The SJRWMD and the SWFWMD used four numbers to identify Florida Land Use and Cover Classification System Level 3 where the SFWMD used three characters for Florida Land Use and Cover Classification System Level 3 and 4 characters for Florida Land Use and Cover Classification System Level 4. The SFWMD land use codes were converted to the system used by the other districts by changing the characters to numbers and multiplying the Florida Land Use and Cover Classification System number by ten. Since the coverages for the different districts have some overlap, the following procedure was established. The SFWMD data were used when available. When SFWMD data were missing or zero, SJRWMD land use code was used. Finally, in areas where neither of the other districts had data, SWFWMD data were used. **Table 15** shows the land use / land cover descriptions. **Figure 67** presents land use for 1995.

Table 15. Land Use / Land Cover Descriptions.

FLUCCS Code	FLUCCS Code Description	FLUCCS Code	FLUCCS Code Description
1000	Urban And Built-Up	1540	Oil and Gas Processing
1009	Mobile Home Units Any Density	1550	Other Light Industrial
1100	Residential Low Density <2 du/ac	1560	Other Heavy Industrial
1110	Fixed Single Family Units <2 du/ac	1590	Industrial Under Construction
1120	Mobile Home Units <2 du/ac	1600	Extractive
1130	Mixed Units (fixed and mobile home units) <2 du/ac	1610	Strip Mines
1190	Low Density Under Construction <2 du/ac	1620	Sand and Gravel Pits
1200	Residential Medium Density 2-5 du/ac	1630	Rock Quarries
1210	Fixed Single Family Units 2-5 du/ac	1640	Oil and Gas Fields
1220	Mobile Home Units 2-5 du/ac	1650	Reclaimed Land
1230	Mixed Units (fixed and mobile home units) 2-5 du/ac	1660	Holding Ponds
1290	Medium Density Under Construction 2-5 du/ac	1700	Institutional
1300	Residential High Density >5 du/ac	1710	Educational Facilities
1310	Fixed Single Family Units >5 du/ac	1720	Religious
1320	Mobile Home Units >5 du/ac	1730	Military
1330	Multiple Dwelling Units Low Rise 1-2 stories	1740	Medical and Health Care
1340	Multiple Dwelling Units High Rise >2 stories	1750	Governmental
1350	Mixed Units (fixed and mobile home units) >5 du/ac	1760	Correctional
1390	High Density Under Construction >5 du/ac	1770	Other Institutional
1400	Commercial and Services	1780	Commercial Child Care
1410	Retail Sales and Services	1790	Institutional Under Construction
1411	Retail Sales and Services - Shopping Centers	1800	Recreational
1420	Wholesale Sales and Services	1810	Swimming Beach
1423	Wholesale Sales and Services - Junk Yards	1820	Golf Courses
1430	Professional Services	1830	Race Tracks
1440	Cultural and Entertainment	1840	Marinas and Fish Camps
1450	Tourist Services	1850	Parks and Zoos
1460	Oil and Gas Storage	1860	Community Recreational Facilities
1470	Mixed Commercial and Services	1870	Stadiums
1480	Cemeteries	1880	Historical Sites
1490	Commercial and Services Under Construction	1890	Other Recreational
1500	Industrial	1900	Open Land <Urban>
1510	Food Processing	1910	Undeveloped Land within Urban Areas
1520	Timber Processing	1920	Inactive Land with Street Pattern
1530	Mineral Processing	1930	Urban Land in Transition

Table 15. Land Use / Land Cover Descriptions (Continued).

FLUCCS Code	FLUCCS Code Description	FLUCCS Code	FLUCCS Code Description
1940	Other Open Land <Urban>	3210	Palmetto Prairies
2000	Agriculture	3220	Coastal Scrub
2100	Cropland and Pastureland	3230	Scrub Jay Habitat
2110	Improved Pastures	3290	Other Shrubs and Brush
2120	Unimproved Pastures	3300	Mixed Rangeland
2130	Woodland Pastures	4000	Upland Forests
2140	Row Crops	4100	Upland Coniferous Forests
2150	Field Crops	4110	Pine Flatwoods
2156	Field Crops - Sugar Cane	4119	Pine Flatwoods - Melaleuca Infested
2200	Tree Crops	4120	Longleaf Pine - Xeric Oak
2210	Citrus Groves	4130	Sand Pine
2220	Fruit Orchards	4140	Pine - Mesic Oak
2230	Other Groves	4190	Other Pines
2300	Feeding Operations	4200	Upland Hardwood Forests
2310	Cattle Feeding Operations	4210	Xeric Oak
2320	Poultry Feeding Operations	4220	Brazilian Pepper
2330	Swine Feeding Operations	4230	Oak - Pine - Hickory
2400	Nurseries and Vineyards	4240	Melaleuca
2410	Tree Nurseries	4250	Temperate Hardwood
2420	Sod Farms	4260	Tropical Hardwoods
2430	Ornamentals	4270	Live Oak
2440	Vineyards	4280	Cabbage Palm
2450	Floriculture	4289	Cabbage Palm - Melaleuca Infested
2460	Timber Nursery	4290	Wax Myrtle - Willow
2500	Specialty Farms	4300	Upland Hardwood Forests - Continued
2510	Horse Farms	4310	Beech - Magnolia
2520	Dairies	4320	Sand Live Oak
2530	Kennels	4330	Western Everglades Hardwoods
2540	Aquaculture	4340	Hardwood Conifer Mixed
2590	Other Specialty Farms	4350	Dead Trees
2600	Other Open Land <Rural>	4370	Australian Pine
2610	Fallow Crop Land	4380	Mixed Hardwoods
3000	Rangeland	4390	Other Hardwoods
3100	Herbaceous	4400	Tree Plantations
3200	Shrub and Brushland	4410	Coniferous Plantations

Table 15. Land Use / Land Cover Descriptions (Continued).

FLUCCS Code	FLUCCS Code Description	FLUCCS Code	FLUCCS Code Description
4420	Hardwood Plantations	6219	Cypress with Wet Prairie
4430	Forest Regeneration Areas	6220	Pond Pine
4440	Experimental Tree Plots	6230	Atlantic White Cedar
4450	Seed Plantations	6240	Cypress - Pine - Cabbage Palm
5000	Water	6250	Hydric Pine Flatwoods
5100	Streams and Waterways	6280	Wet Pinelands
5200	Lakes	6300	Wetland Forested Mixed
5210	Lakes larger than 500 acres	6400	Vegetated Non-Forested Wetlands
5220	Lakes larger than 100 acres - less than 500 acres	6410	Freshwater Marshes
5230	Lakes larger than 10 acres - less than 100 acres	6411	Freshwater Marshes - Sawgrass
5240	Lakes less than 10 acres	6412	Freshwater Marshes - Cattail
5300	Reservoirs	6420	Saltwater Marshes
5310	Reservoirs larger than 500 acres	6430	Wet Prairies
5320	Reservoirs larger than 100 acres - less than 500 acres	6439	Wet Prairies - with Pine
5330	Reservoirs larger than 10 acres - less than 100 acres	6440	Emergent Aquatic Vegetation
5340	Reservoirs less than 10 acres	6450	Submergent Aquatic Vegetation
5400	Bays and Estuaries	6500	Non-Vegetated
5410	Embayments opening directly into Gulf or Ocean	6510	Tidal Flats
5420	Embayments not opening directly into Gulf or Ocean	6520	Shorelines
5500	Major Springs	6530	Intermittent Ponds
5600	Slough Waters	6540	Oyster Bars
6000	WETLANDS	7000	Barren Land
6100	Wetland Hardwood Forests	7100	Beaches Other Than Swimming Beaches
6110	Bay Swamps	7200	Sand Other Than Beaches
6120	Mangrove Swamps	7300	Exposed Rock
6130	Gum Swamps	7310	Exposed Rock with Marsh Grasses
6140	Titi Swamps	7400	Disturbed Lands
6150	Stream and Lake Swamps (Bottomland)	7410	Rural Land in Transition
6160	Inland Ponds and Sloughs	7420	Borrow Areas
6170	Mixed Wetland Hardwoods	7430	Spoil Areas
6171	Mixed Wetland Hardwoods - Willows	7440	Fill Areas (Highways - Railways)
6172	Mixed Wetland Hardwoods - Mixed Shrubs	7450	Burned Areas
6200	Wetland Coniferous Forests	8000	Transportation Communications And Utilities
6210	Cypress	8100	Transportation
6218	Cypress - Melaleuca Infested	8110	Airports

Table 15. Land Use / Land Cover Descriptions (Continued).

FLUCCS Code	FLUCCS Code Description	FLUCCS Code	FLUCCS Code Description
8110	Airports	8210	Transmission Towers
8120	Railroads	8220	Communication Facilities
8130	Bus and Truck Terminals	8290	Communication Facilities Under Construction
8140	Roads and Highways	8300	Utilities
8150	Port Facilities	8310	Electrical Power Facilities
8160	Canals and Locks	8320	Electrical Power Transmission Lines
8170	Oil Water or Gas Long Distance Transmission Lines	8330	Water Supply Plants
8180	Auto Parking Facilities	8340	Sewage Treatment
8190	Transportation Facilities Under Construction	8350	Solid Waste Disposal
8200	Communications	8390	Utilities Under Construction

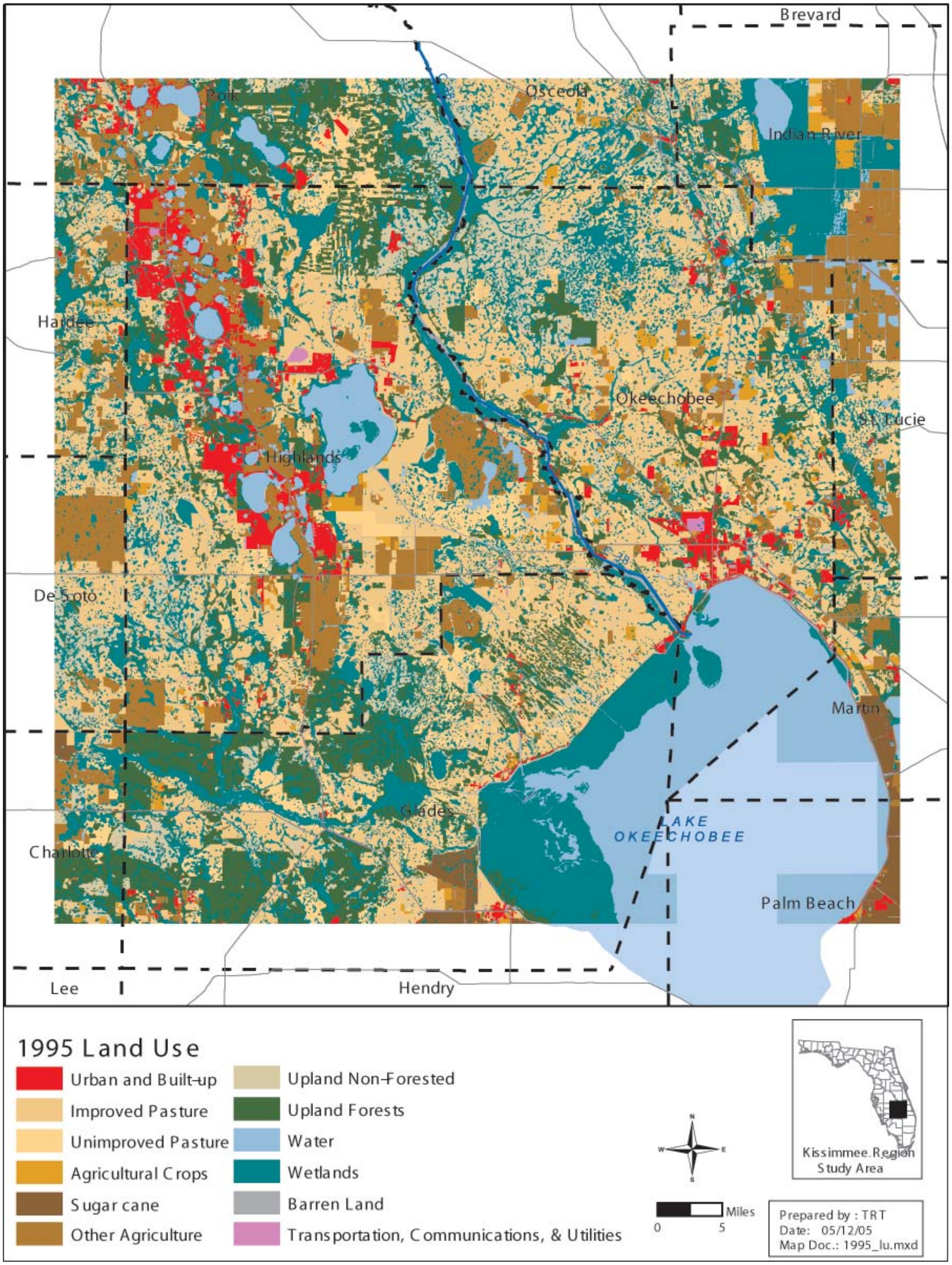

Figure 67. Land Use 1995.

Recharge for Irrigated Areas

The AFSIRS program has the ability to estimate irrigation demands for different land uses/crop types. The program requires input on the crop types, including information on monthly crop coefficients, root depths and allowable soil water depletion. The crop coefficient is a ratio of the evapotranspiration for a specific crop and the reference evapotranspiration. The program uses information on the efficiency of the irrigation systems to determine how much supplemental irrigation is required by the system. When an irrigation system is inefficient, the excess water is returned to the groundwater system as recharge (Giddings and Restrepo 1995). For the calibration run of the Lower Kissimmee Groundwater Model, the irrigation demands from AFSIRS were not used to estimate water use for irrigation, but instead used for recharge calculations. The permit database was used to calculate agricultural demands as further explained the Applied Stresses section, which follows. For the model simulation runs the consumptive water use for irrigation was recalculated using AFSIRS based on land use instead of on permit database values.

Applied Stresses

The groundwater system reacts to the stresses imposed on it. While recharge and irrigation add water to the Surficial Aquifer System, wells and pumps take water out of the system. The primary stress on deeper aquifers is from consumptive use. The consumptive use is divided into the categories of for public water supply, domestic self-supply and agricultural self-supply. For modeling purposes it was assumed that the domestic self-supply was an insignificant amount of the total water demand. The current model is a groundwater model so the demands to the surface water were subtracted from the total consumptive use demands, leaving only the demands from the groundwater system.

Public Water Supply

All of the water management districts assign a use type to their permits. Within the SFWMD boundaries in the model area, there are 67 permittees with 118 groundwater wells designated as public water supply wells (**Figure 68**). The public supply wells located in the SWFWMD serve the lake communities on Lake Wales Ridge.

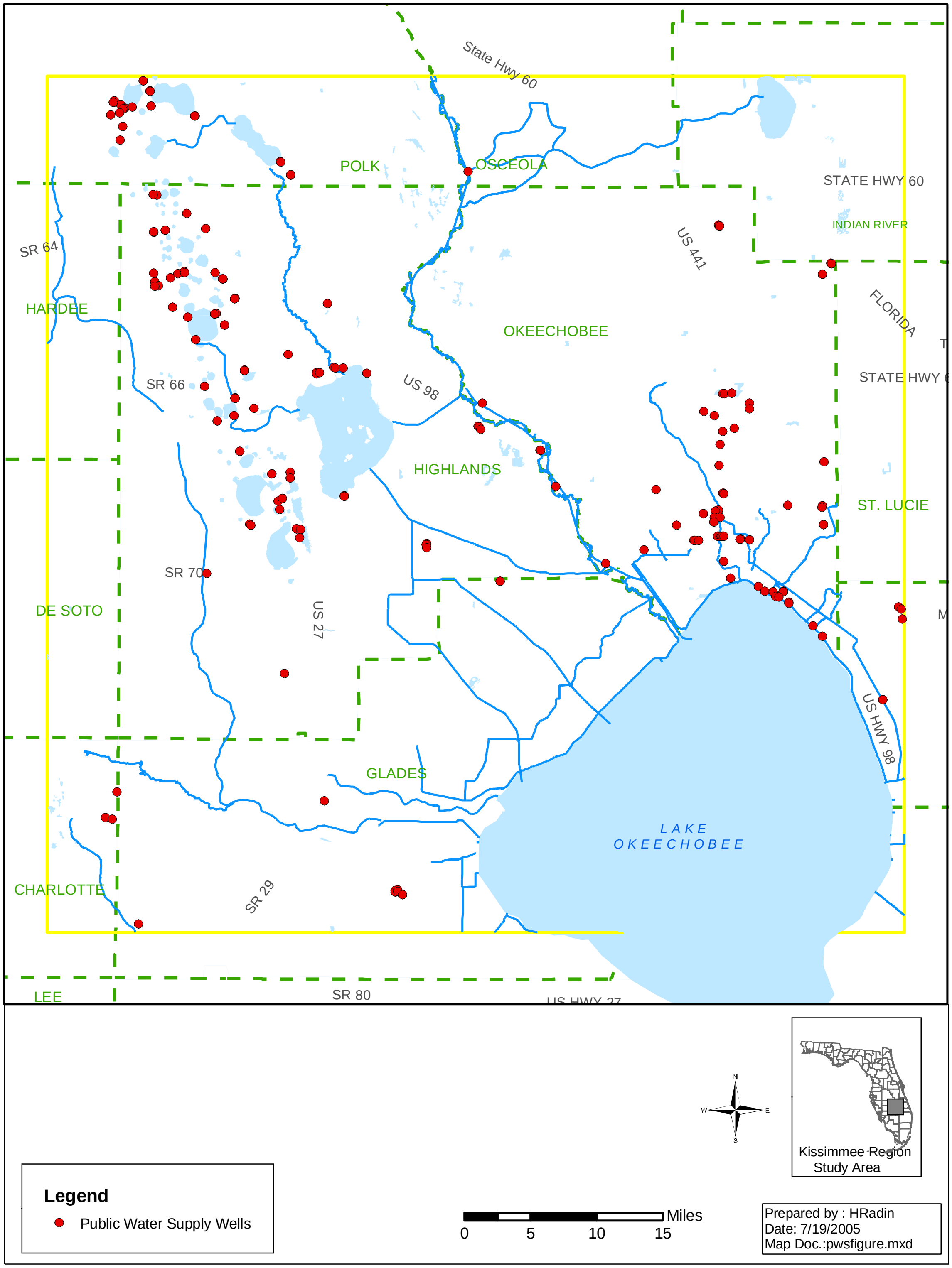

Figure 68. Public Water Supply Wells.

Agricultural Demands

Most of the wells in the model are used for irrigation purposes. Included in non-public water use are agriculture, industry, golf course, nursery and recreation areas. Most of the non-public water supply wells are not metered, so permitted pumpage was used. Many permittees obtain a permit for pasture, but in most cases the pasture areas are not irrigated. Therefore allocation to pastures was removed and those permits with multiple crops had their allocations distributed among their other facilities. The agricultural wells are displayed in **Figure 69** and more information on the agricultural wells used is available in **Appendix C**.

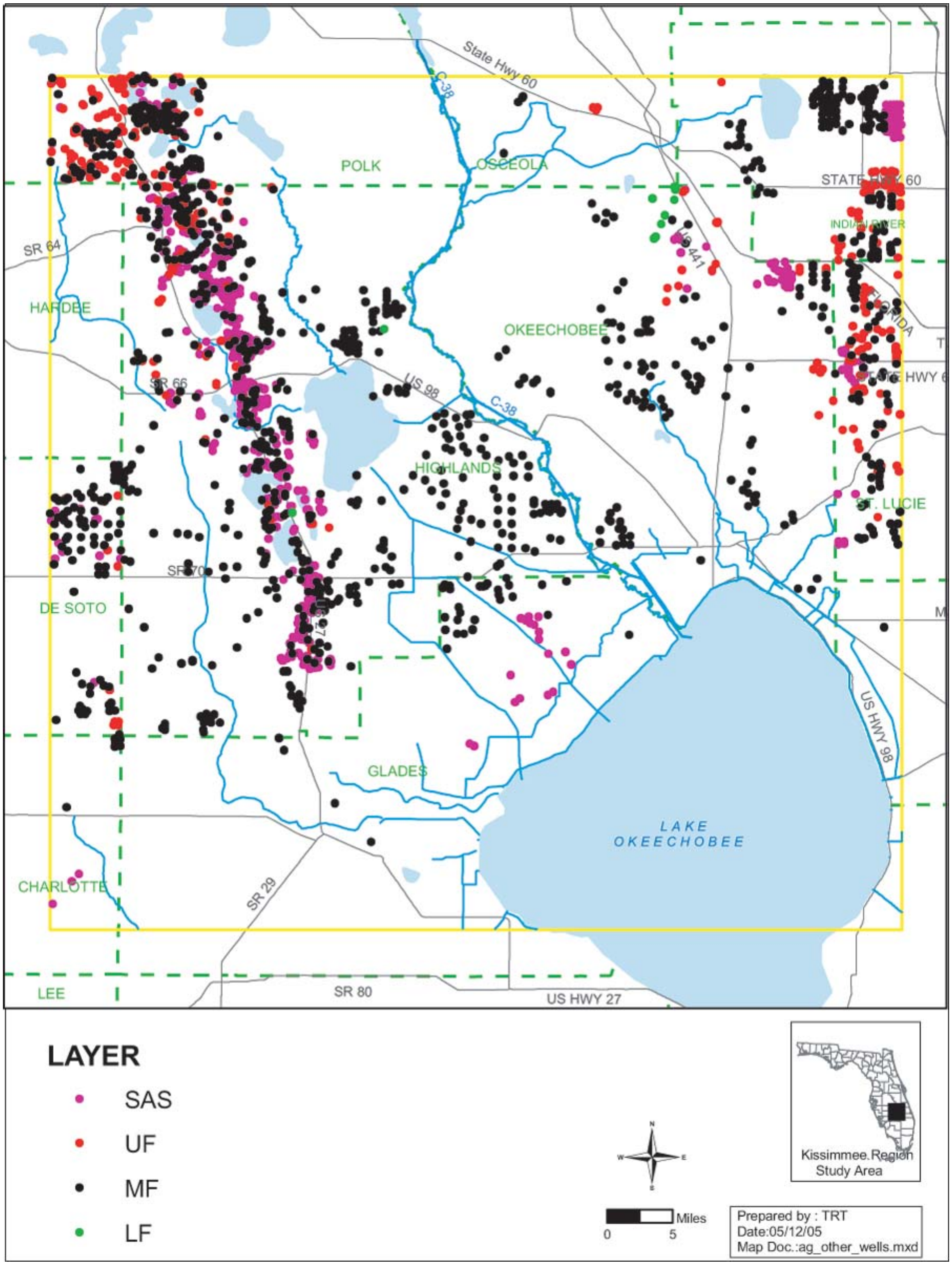

Figure 69. Agricultural and Other Irrigated Wells.

Groundwater Withdrawal

The model area includes areas in three water management districts – South Florida Water Management District, St. Johns River Water Management District and Southwest Florida Water Management District. Consumptive use data were gathered from all three districts. Consumptive use includes both public water supply and agricultural supply. Surface water consumption was not included in the model. Each district maintains their data differently. The databases were queried in 2003, so data provided represents the stress at that time. Based on the land use files from 1995 and 2000, it does not appear there was a significant change in the water use from 1995.

South Florida Water Management District

The South Florida Water Management District (SFWMD) issues consumptive use permits, which include both surface water and groundwater sources. The permits do not specify the distribution of the consumptive use between the surface and groundwater sources. The permits specify the maximum amount of water the permittee may use. Some of the permits assign the allocation by maximum per month, but most assign the use by year.

The average daily consumption was calculated and converted to the units of feet per day. The permits provide a list of the facilities (pumps and wells), the well depths and pump and well capacities. Most of the facilities are not metered. For the calibration of the Lower Kissimmee Basin Groundwater Model the permit database was used to estimate the water use. It was assumed that the permittees do not use their maximum allocation.

The water supply planning process needs to consider that the permittees may use their entire allocation, however, and impacts to aquifers should be carefully evaluated in that event. A limited amount of permits stipulate the allocation for both groundwater sources and the allocation for surface water sources, sometimes based on crop type. When the permits did not divide the allocation between groundwater and surface water sources, the allocation was divided based on the capacity of the facilities. Each facility in a permit was assigned a percentage of the allocation based on the percentage of the facility capacity/ total capacity of all the facilities in the permit. Once the allocations were assigned to all the facilities, the surface water sources were removed from the "well file", leaving only wells. The locations for most of the facilities were known, and were assigned to a cell within the permit boundary if unknown. If permit boundaries were not delineated, the withdrawal location was determined from the address or township/section/range in combination with land use. In order to distribute the groundwater allocation to the model layers, the depth of the facility was used and compared with the hydrostratigraphy layers. Some facilities list a source aquifer in the permit database. This was compared to resulting well depth to see if the depth of hydrostratigraphy matched the permit database assignment. If casing information was available and the well was open to more than one layer, the allocation was divided evenly between the layers. Wells coded as standby wells were removed from the dataset.

Special Case – Fort Basinger: The application of the previous estimated method to calculate groundwater withdrawals for Fort Basinger (Permit 28-00146W) resulted in simulated head values, which were much lower than observed water levels. Fort Basinger is one of the permittees submitting a report of water used. The consumption report for 1995 was only 1/5 of the permitted water use. The consumption report also includes how much water was used from each facility. Some of the wells were not being used at all. Therefore the actual water use for 1995 was used instead of the estimated use for this permit. The differences between simulated and observed water levels were now within calibration range.

Special Case – Brighton (Seminole Reserve): The Seminole Nation submitted a work plan with water use estimates for each of their reservations to the SFWMD. Only the Brighton reservation is within the model area. Murray Consultants, 1999 provided a table of information on the Tribe Facilities and an estimate of the Tribes water needs from each source. The groundwater use was divided among the wells based on the capacity of each facility. All the wells were in the Surficial Aquifer System.

Southwest Florida Water Management District

Southwest Florida Water Management District (SWFWMD) assigns the source allocation (groundwater/surface water) for each facility it permits. The groundwater wells were selected. Some of the wells were open to more than one aquifer. In those cases, the allocation was divided evenly between the layers. The well depths were compared with the model hydrostratigraphy to assign model layers. Wells with no assigned allocation were removed from the database.

If only total depth was provided, and no specific aquifer was designated, and the total depth indicated it was in the Floridan Aquifer System, the allocation was divided among the sub-aquifers above that total depth (usually Upper and Middle Floridan)

St. Johns River Water Management District

St. Johns River Water Management District (SJRWMD) collects the data in two spreadsheets. One includes permit information and maximum allocation to groundwater or surface water, and the other contains facility information. Often there are multiple wells or pumps for each permit. The groundwater uses were divided between the facilities based on capacity. If capacity information was not available, the allocation was divided evenly. When the depths of the wells and or casing information were available, the wells were compared with the model hydrostratigraphy to assign a model layer. If depths and or casing information were not available and the SJRWMD had assigned an aquifer, the assignment was used. Otherwise the well allocation was divided between the Upper Floridan Aquifer and Middle Floridan Aquifer.